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ART. I.—*Contributions to Meteorology, being results derived from an examination of the Observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Seventh paper. With plates I, II and III.

[Read before the National Academy of Sciences, Washington, April 18, 1877.]

Rain-areas—their form, dimensions, movements, distribution, etc.

IN my last paper I examined all those cases in which the rain-fall was uncommonly great at any one of the Signal Service stations during a period of fifteen months (Sept. 1872, to Nov. 1873). I propose now to consider those cases in which the *total* rain-fall for all the stations was uncommonly great. The following table exhibits all the cases in which the total rain-fall at all the stations amounted to at least eight inches in a period of eight hours. Column 1st contains the number of reference; column 2d shows the day and hour of observation (the numeral one denotes the observation at $7^h\ 35^m$ A. M.; two denotes the observation at 4.35 P. M.; and three denotes 11 P. M.) column 3d shows in inches the total rain-fall at all the stations during the preceding eight hours; column 4th shows the station at which the greatest rain-fall was recorded; column 5th shows the amount of rain observed at the station mentioned in column 4th; column 6th shows the state of the barometer at the same station; column 7th shows the state of the barometer at the nearest center of minimum pressure; column 8th shows the direction of the rain center mentioned in column 4th from the center of low pressure mentioned in column 7th; column 9th shows the distance of the rain center from the center of low

Total rain-fall at all the stations amounting to at least eight inches in eight hours.

No.	Date.	Total rain-fall.	Station of greatest rain.	Rain at do.	Bar. at do.	Low bar.	Rain center from Low. Direction.	Rain center from Low. Distance.	Wind at prev.ob.	Wind at date.
	1872.									
1	Sept. 11.3	10·76	Marquette.	1·91	29·80	29·74	N. 5° W.	287	S.E. 1	W. 1
2	12.2	9·93	Saugeen.	1·74	·74	·68	N. 40 W.	78	S. 3	Calm.
3	Oct. 6.3	8·75	Vicksburg.	1·05	30·02				N. 8	E. 3
4	7.2	8·58	Montreal.	1·35	29·90	·81	North.	156	S.W. 2	N.E. 3
5	22.3	8·30	Jacksonville.	2·43	·99				N.E. 12	E. 13
6	23.1	9·34	Jacksonville.	2·05	·83				E. 13	W. 1
7	25.1	8·91	Norfolk.	3·41	·95	·95	*	0	E. 13	S.E. 8
8	26.1	8·80	Philadelphia.	2·09	·78	·74	S. 65 E.	137	E. 20	S.W. 12
9	Nov. 6.3	9·91	Montgomery.	2·73	·95				E. 3	S..E 22
10	7.1	13·52	New York.	2·50	·68	·33	S. 54 E.	777	S.E. 4	N.W. 10
11	Dec. 18.2	8·77	New Orleans.	2·20	30·08				S.W. 6	N.E. 8
12	20.1	14·49	New York.	1·70	29·78	·43	S. 55 E.	287	N.E. 17	N.W. 20
13	26.1	9·46	Norfolk.	2·08	·46	·46	*	0	N.E. 21	N. 20
	1873.									
14	Jan. 2.2	9·12	Keokuk.	1·63	·35	·23	S. 44 W.	134	Calm.	W. 12
15	3.1	8·63	New York.	1·80	·83	·09	S. 57 E.	761	N.E. 16	E. 6
16	5.1	12·74	Lake City.	2·00	·89				S.E. 4	S.E. 7
17	5.2	16·25	Philadelphia.	2·18	·61	·45	S. 58 E.	218	N.E. 20	N.E. 8
18	16.1	10·08	New Orleans.	2·01	·92				S. 8	N.W. 12
19	17.1	8·05	Philadelphia.	1·07	·80	·54	S. 36 W.	630	S.W. 18	N.W. 18
20	Feb. 16.1	10·57	Louisville.	1·60	·56	·49	East.	195	N.E. 8	Calm.
21	16.2	9·87	Cape May.	1·54	·66	·55	N. 87 E.	448	E. 18	S. 6
22	26.2	8·88	Knoxville.	1·23	·80	·36	S. 39 E.	507	E. 5	Calm.
23	Mar. 29.1	10·65	Lake City.	2·00	·97				N.E. 8	N.W. 12
24	29.2	10·48	Oswego.	1·48	·01	·01	*	0	S.E. 12	N.E. 12
25	April 8.1	8·70	Indianapolis.	1·08	·71	·64	N. 46 E.	343	N.E. 7	E. 4
26	8.2	8·57	St. Louis.	1·65	·64	·52	N. 82 W.	245	N. 34	W. 9
27	May 1.2	9·37	Montgomery.	3·05	·87				S.E. 4	S.E. 4
28	2.1	11·78	Wilmington.	1·01	·88				S. 12	N.E. 2
29	2.2	8·49	Wilmington.	1·02	·68				N.E. 2	S.W. 30
30	8.1	8·33	Lynchburg.	1·37	·98	·59	S. 57 E.	562	N.E. 12	N.E. 8
31	June 23.1	8·65	St. Paul.	2·30	·57	·52	S. 67 E.	93	S.E. 18	S.W. 2
32	30.2	9·23	Port Stanley.	1·81	·56	·36	S. 60 E.	591	S.W. 3	S.W. 3
33	July 17.3	10·88	Buffalo.	2·00	·64	·64	*	0	S.W. 14	S.W. 7
34	27.2	9·63	Washington.	2·12	30·11	·72	S. 63 E.	1175	S. 10	W. 8
35	Aug. 12.2	8·45	Galveston.	1·68	·04				N. W. 4	W. 2
36	13.1	9·52	Philadelphia.	2·31	·04	·92	N. 73 E.	346	E. 16	N.E. 12
37	13.2	8·27	Philadelphia.	2·17	29·97	·85	N. 41 E.	348	N.E. 12	N.E. 22
38	18.2	8·58	Wilmington.	1·50	30·05				Calm.	S.W. 6
39	21.1	9·56	Galveston.	3·67	29·95				E. 5	Calm.
40	Sept. 19.2	11·39	Cape May.	1·92	·70	·57	S. 12 W.	487	E. 3	N.W. 8
41	19.3	8·96	Mt. Washington.	2·20	·86	·59	North.	202	S.W. 24	W. 12
42	24.1	9·51	Mt. Washington.	1·55	30·12	·86	N. 7 E.	222	W. 6	N.W. 12
43	28.1	8·69	Fort Gibson.	1·01	29·75				E. 7	S.E. 6
44	Oct. 19.3	9·82	New London.	2·25	·80	·52	N. 34 E.	329	S.E. 2	S.E. 24
45	20.1	17·65	Philadelphia.	1·96	·47	·45	N. 16 W.	89	E. 12	N. 12
46	20.2	12·27	Rochester.	1·38	·65	·26	N. 26 W.	273	N. 20	N.E. 25
47	20.3	9·86	Buffalo.	1·23	·35	·30	N. 54 W.	160	N. 23	N. 14
48	27.1	8·30	Knoxville.	1·24	·79	·29			N.W. 24	W. 25
49	27.2	8·68	Cape May.	0·90	·63	·22	S. 35 W.	410	S. 26	S.W. 4
50	Nov. 8.1	8·64	Boston.	1·75	·58	·48	N. 84 E.	225	E. 12	N.E. 17
51	18.1	8·23	Boston.	1·50	28·69	28·66	N. 48 E.	101	N.E. 28	W. 16
52	18.2	9·23	Sydney.	1·37	29·09	28·47	N. 75 E.	332	E. 10	S.E. 18
53	24.1	11·16	Nashville.	1·08	·86	29·49	S. 48 W.	520	Calm.	W. 8
54	24.2	14·69	New London.	2·80	·30	·27	S. 61 W.	90	S.E. 14	N. 12
55	27.2	9·71	Charleston.	1·75	·91				Calm.	N. 8

pressure expressed in English miles; column 11th shows the direction and force of the wind at the place mentioned in column 4th and at the date given in column 2d; and column 10th shows the direction and force of the wind at the observation next preceding the date mentioned in the table.

For each of the cases named in this table, the curves of equal rain-fall have been accurately drawn upon maps of the United States, and these curves have been carefully compared. The following table shows the geographical extent of some of these rain-areas. Column 1st shows the number of reference taken from the preceding table; column 2d shows in English miles the greatest and least diameters of the area over which the rain-fall was at least one inch in eight hours; and column 3rd shows the greatest and least diameters of the area over which the rain-fall was at least half an inch, in eight hours.

Dimensions of Rain-areas.

No.	Area of one inch rain.	Area of half inch rain.	No.	Area of one inch rain.	Area of half inch rain.	No.	Area of one inch rain.	Area of half inch rain.
10	720–230	920–398	17	443–167	714–393	20	338–173	890–406
9	605–334	668–430	16	440–160	858–356	54	338–194	458–358
45	546–318	724–350	27	380–296	468–390	7	320–288	394–312
39	490–188	514–236	32	374–150	796–340	5	312–276	394–394
55	468–162	652–312	6	360–304	440–402	11	300–174	494–300
31	446–216	774–332	8	354–144	436–266	18	242–162	858–224

The form of these rain-areas is sometimes quite irregular but generally it approximates to an ellipse of which the major axis is not quite double the minor axis. This elongated form of rain-areas is more noticeable in storms which prevail near the Atlantic coast, than it is in regions remote from the ocean. It will be seen that in three cases the area of one inch rain-fall exceeded 500 miles in length, and in six cases the area of one half inch rain-fall exceeded 750 miles in length. In number ten, the area of one quarter inch rain-fall was 1,180 miles by 500 miles; in number twenty, this area was 1,000 miles by 572 miles, and in two or three other cases the dimensions of the rain-areas were nearly as great. Frequently the entire rain-area is an oval figure whose length exceeds 1,000 miles, and whose breadth exceeds 500 miles.

It was shown in my sixth paper, that south of latitude 36° rain-areas are as frequently under the influence of an area of high barometer as of an area of low barometer. In columns 7, 8 and 9, of the table on page 2, I have therefore left blanks for the southern stations. The numbers in column 8th, for the northern stations, show that in seventeen cases the rain center was north of the center of low pressure, and in sixteen cases it was south of this center. In twenty cases the rain center was

east of the center of low pressure, and in twelve cases it was west of this center. If, however, we consider the middle of the rain-fall as corresponding to a date four hours preceding the barometric observation, we shall find that in four of these cases, viz: numbers 1, 2, 14, and 54, the principal rain-fall occurred when the rain center was east of the center of low pressure, or at least very near it. In several of the cases, however, the rain center was clearly west of the center of low pressure, and in some of the cases the rain-fall apparently had a decided influence upon the direction of the storm's progress. This was specially true of numbers 45, 46 and 47, in which case the center of minimum pressure moved *westward* instead of eastward. As this example is a very remarkable one, I will consider it particularly.

On the morning of October 19th 1873, along the coast of North Carolina, Virginia and New Jersey, light winds from the east, or southeast generally prevailed, while west of Virginia and Pennsylvania the winds were generally from the west or northwest. This opposition of the winds was attended by a rain-fall, which in the afternoon became general along the Atlantic coast from Wilmington to Boston and extended inland 300 or 400 miles. The barometer fell steadily during the day, and a center of minimum pressure which had prevailed for twenty-four hours near the coast of Florida, advanced rapidly northward. During the evening of the 19th the same winds continued with increasing strength; the rain-fall increased especially about Washington and New London; the barometer continued to fall, and the center of minimum pressure advanced to Norfolk. On the morning of the 20th the same system of winds prevailed but had advanced further northward, the southeast winds near the coast extending from New York to Nova Scotia, and having a velocity of twelve to twenty-five miles, and were opposed by fresh winds from the north and west in the vicinity of Lakes Erie and Ontario. At Quebec the wind blew from the east, forty-six miles per hour, and on Mt. Washington the wind blew from the southeast seventy-five miles per hour. The total rain-fall at all the stations during the preceding eight hours was greater than was recorded for any other equal period during the fifteen months under discussion. The center of minimum pressure had now reached Cape May, and the center of the rain area was 250 miles further north. During the 21st the system of east winds near the coast of New England and Nova Scotia had pushed further into the interior, and in the afternoon extended to Rochester, which was now the center of greatest rain-fall, while the center of minimum pressure moved slowly in the same direction. The wind at Quebec still blew from the east, forty-two miles per hour, and on Mt. Wash-

ington it blew from the southeast, seventy-eight miles per hour. During the evening of the 20th the same system of winds continued, but the center of the rain-area was at Buffalo, and the center of minimum pressure advanced in the same direction. The wind at Quebec still blew from the east forty-five miles per hour, and on Mt. Washington from the southeast fifty miles per hour. On the morning of the 21st, southerly and easterly winds extended from the coast of New England to Lake Erie, where was now the greatest rainfall, and also the center of minimum pressure. At Grand Haven on Lake Michigan, the wind blew from the north thirty-two miles per hour, and on Mt. Washington from the southeast fifty-five miles per hour. On the afternoon of the 21st the system of winds was nearly the same, but their intensity was sensibly diminished. On Mt. Washington the wind blew from the southeast thirty-eight miles per hour. The center of minimum pressure had now advanced westward nearly to Lake Michigan, a result which was apparently due to a second area of low pressure which came from the northwest and coalesced with the one which we have been considering. During the evening of the 21st the easterly motion of the winds near the coast of New England was very much diminished; the rainfall was also diminished, and the center of minimum pressure advanced a little to the north. On the morning of the 22d the rain-fall had nearly ceased, the winds were generally moderate, and the center of minimum pressure moved a little toward the north east. During the 22d there were two centers of maximum pressure in the southern part of the United States, and under their influence southerly winds generally prevailed east of the Mississippi, while in the northwestern States the winds were from the northwest. Hence resulted a circulation of the winds about Lake Superior, and the center of minimum pressure moved in that direction. On the 23d the pressure in the southern States increased; southerly winds generally prevailed throughout the Lake region, and the center of minimum pressure was apparently pushed still further toward the northwest, but as this center had now passed beyond the stations of observation, it is impossible to locate it with precision.

Plate I shows the curves of equal rain-fall for October 20, 7.35 A. M. The outer curve shows the extreme limits of the rain-area during the preceding eight and one-half hours; the next curve shows the limit of one half inch rain-fall; the third curve shows the area over which the rain-fall was at least one inch; and the inner curve shows the area of one and a half inch rain-fall. At Philadelphia and Burlington the rain-fall was 1·96 inch during the eight and one-half hours, and it is probable that near the center of the rain area the rain-fall ex-

ceeded two inches. The successive positions of the center of minimum pressure are indicated by the figures 19·2, 19·3, 20·1, etc., and the undulating line connecting these points represents the path of the center of minimum pressure from October 19th to October 22d. The arrows at the several stations represent the direction of the winds for October 19th, 11 P. M., which was the time of commencement of the rain-fall represented upon the map.

This example presents a very unusual case of a storm center traveling for several days toward the northwest. This result was apparently produced by a wind of unusual violence setting in from the Atlantic Ocean, and meeting with opposing winds from the interior caused a very unusual rain-fall, and the center of minimum pressure followed the center of the rain-area. These facts seem to indicate that a heavy rain-fall extending over a large area has a decided influence in determining the course of a storm center.

In No. 26 the principal rain-fall was on the northwest side of the center of minimum pressure but not over 150 miles from it. In No. 53 the principal rain-fall was on the southwest side of the center of minimum pressure, and these two cases, together with No. 12 on page 15 of my last paper, indicate that in the neighborhood of Kentucky it is not uncommon for the principal rainfall to occur after the center of low pressure has passed eastward.

In Nos. 40 and 49 the rain-fall at Cape May was greater than at any other station, but there was at the same time another rain-area of much greater extent near the center of minimum pressure. The rain-fall at Cape May was apparently the result of a local cyclone which did not greatly affect the height of the barometer.

In No. 19 there was a center of low pressure in Nova Scotia, but it seemed to have little influence upon the winds near Philadelphia. There was a center of high pressure in Iowa, and the winds near the Lake region were generally from the northwest. At Norfolk the wind was from the south, and a new center of low pressure was forming near the coast of North Carolina. The rain about Philadelphia on the morning of January 17th was apparently due to a local cyclonic movement, more than to the influence of the low center in Nova Scotia.

The average distance of the center of greatest rain-fall from the center of low pressure for cases north of latitude 36°, is 300 miles, but it sometimes exceeds 750 miles.

In 19	cases	the distance was	less than 250 miles.
11	"	"	between 250 and 500 miles.
5	"	"	" 500 and 750 miles.
3	"	"	over 750 miles.

In No. 34 (page 2) there was a center of low pressure in Minnesota, but it seemed to exert no control over the winds in the eastern and southern parts of the United States. Here there were five centers of local cyclonic movement, each of which became the center of a rain-area as shown on Plate II. Neither of these centers became a center of low pressure although the rain-area near Washington continued for sixteen hours.

In No. 10 there was a center of low pressure over Lake Superior, but this was so distant that it exerted but little influence over the winds near the Atlantic coast. On the evening of November 6th, winds from the south and east generally prevailed along the entire Atlantic coast, and these being opposed by westerly winds (the result of a high barometer in Tennessee), there was an extensive rain on the night of November 6th, which was especially heavy along the coast from Georgia to Massachusetts. This rain-fall seemed to have a decided influence in accelerating the movement of the center of low pressure, as was mentioned in my last paper, p. 16.

No. 15 was in many respects similar to No. 10, but it did not produce the same effect on the movement of the low center, perhaps owing to the influence of another rain-area which prevailed near Montreal.

No. 19 has already been referred to; see preceding page.

In No. 32 the center of lowest pressure was beyond Lake Superior, but the barometer was quite low (29·56) at Port Stanley, and here there was apparently a local cyclone resulting in a heavy rain-fall.

No. 30 shows the influence of an area of high pressure combined with an area of low pressure. On the 7th of May there was an area of low pressure near the mouth of the Ohio River, and an area of high pressure in New England, which gave rise to a system of southeast winds along the Atlantic coast, and extending to the Lake region. The result was a slight rain-fall over a large area of territory, but the rain was greatest about Lynchburg, near which place there was some evidence of cyclonic motion. Perhaps the Alleghany Mountains had some influence in determining the upward movement of the southeast current near this place.

No. 22 appears to have resulted from east winds along the Atlantic coast opposed by west winds near the Mississippi valley, on the south side of an area of low pressure.

No. 53 has already been referred to on page 6, and it is remarkable that the center of low pressure moved towards the northeast at the rate of 54 miles per hour, leaving the center of principal rain-fall almost exactly in its rear. There were, however, at the same time two other rain areas of considerable

extent on the northeast side, one about Baltimore and the other about Montreal.

From the preceding statement we perceive that in the United States, south of latitude 36°, great rain-falls are accompanied by a cyclonic movement of the air which sometimes appears to be the result of a neighboring area of low pressure, and sometimes of an area of high pressure, and the latter case is about as frequent as the former. North of latitude 36° rain-areas are most frequently associated with areas of low barometer and generally they are found on the east side of the center of low pressure; but occasionally they are found on the west side of the center of low pressure, and this case occurs most frequently in the neighborhood of the Ohio valley. Extensive rain-areas sometimes occur in the Northern States at a great distance from a low center, where they appear to be as much under the influence of a center of high pressure as of a center of low pressure, and in these cases there are generally indications of a local cyclonic movement of the atmosphere.

Of the fifty-five cases enumerated in the table on page 2, in thirty-eight cases the wind blew from some quarter between northeast and southeast, either at the date given in the table or at the time of the preceding observation. Of the seventeen remaining cases, in five of them the air was reported as *calm*; in three of them the wind was from the south, and two of the cases occurred on the summit of Mt. Washington. In one of the remaining cases the velocity of the wind was only two miles per hour; in another case the velocity was three miles per hour; in a third case it was seven miles per hour, and in a fourth case it was nine miles per hour. There remain only three cases in which at both the observations the wind was strong from some quarter between north and southwest. These cases are Nos. 19, 47 and 48.

In No. 19, the winds upon the Atlantic coast near Philadelphia were generally from the south or southeast, while at a distance of 300 miles from the coast, the winds were from the west or northwest. It seems probable that this northwest current crowded under the southeast current lifting it up from the earth's surface and thus condensing its vapor, and that the south wind at Philadelphia was the result of the meeting of the southeast wind from the ocean with the northwest wind of the interior.

In No. 47, as has been already mentioned on page 4, the center of the rain-area was on the northwest side of the center of low pressure. It seems probable that in this case the violent southeast wind from the ocean extended further west than Buffalo, and that its vapor was condensed by its being elevated from the earth's surface by the crowding of the northwest wind

beneath it. This fact is distinctly indicated by the following observations for October 20th, 7.35 A. M., from stations west of the limits of the rain area.

	WIND.		Direction of upper clouds.	Amount of clouds.
	Direction.	Velocity.		
Alpena	North.	9 miles.	S.W.	$\frac{4}{4}$
Detroit	North.	12 "	South.	$\frac{4}{4}$
Louisville	North.	16 "	South.	$\frac{1}{4}$
Toledo	North.	15 "	S.E.	$\frac{4}{4}$

In No. 48, south winds generally prevailed in Georgia and the Carolinas, with cold winds from the west and northwest in the Northwestern States. This westerly current probably pushed under the south wind from the ocean and lifting it up from the earth's surface condensed its vapor, and it is presumed that this south wind prevailed as an upper current at many places where the northwest wind prevailed at the surface. We thus see that during heavy rain-falls the wind generally blows from some quarter between south and northeast, or if it blows from any other quarter its velocity is quite small; but occasionally a great rain-fall occurs with a strong wind from some quarter between north and southwest and in such cases it is presumed that at the same time an easterly wind prevails at those places as an upper current. This upper current from the east is generally concealed by the lower clouds whose motion is nearly the same as that of the surface wind; but when the lower clouds are broken, the movement of this upper current can sometimes be seen.

The average velocity of the wind at the date of the observations in the table on page 2, was ten miles per hour, and at the date of the preceding observations it was eleven miles per hour; and in only six cases did the velocity rise as high as twenty-five miles per hour, either at the date given in the table or at the preceding observation. Thus we see that the heaviest rain-falls are seldom accompanied by very high wind.

One of the most noticeable facts connected with extensive rain-falls is the tendency to the formation of several centers of precipitation. If in each of the cases mentioned in the table on page 2 we trace the boundary of that area over which the rain-fall was at least one inch, we shall find that in half of these cases there were two such areas distinct from each other, and in eleven cases there were three such areas. If we trace the area of a rain-fall of at least one-half inch, we shall find that in forty-five cases there were at least two distinct rain-areas, and in twenty-nine cases there were three or more such areas. If we trace the area of a rain-fall of one-fourth inch or more, we shall find that there are only three cases, viz:

Nos. 8, 24, and 45, in which there were not at least two distinct rain-centers. In No. 45 there was apparently a subordinate rain-center, near Charleston, and in No. 8 there was a fall of 0·14 inch at Alpena, which was beyond the principal rain-area. Thus we see that when there is an extensive rain-fall in the United States there is almost invariably more than one center of precipitation, and this fact suggests the idea that those conditions which are favorable to rain-fall at one locality, are generally favorable to rain-fall over a much larger district, and this often results in a simultaneous precipitation at several points remote from each other.

Plate II exhibits the rain-areas for July 27th, 1873, at 4.35 P. M. Here we find four rain-areas showing a rain-fall of at least one inch, and an equal number of areas showing a smaller rain-fall. The following table shows the greatest amount of rain observed at any station within each of these areas:

Rain-fall July 27, 1873, 4.35 P. M.

Washington	2·12 inches.	Shreveport	0·84 inch.
New York	1·54 "	Breckenridge	·45 "
Nashville	1·35 "	Wilmington	·18 "
Eastport	1·00 "	Denver	·09 "

It is possible that the Washington rain area was not entirely distinct from the New York area, but the observations clearly indicate two centers of greatest rain-fall. During the time of this rain-fall, the barometer was a little above 30 inches at all of the stations here mentioned, except Breckenridge. The arrows show the direction of the wind at 4.35 P. M. There were decided local cyclones near Washington, New York, and Nashville, and indications of opposing winds near Shreveport and Breckenridge. It is presumed that if the stations had been sufficiently numerous, the same fact would have been established for each of the rain-areas. As the largest of these cyclonic areas had a diameter less than a 1,000 miles, and the velocity of the winds was almost everywhere less than ten miles per hour, no perceptible effect was produced upon the barometer.

A considerable number of the cases mentioned in the table on page 2, exhibit a variety of rain-areas nearly as remarkable as that shown in Plate II. Among these may be mentioned Nos. 1, 2, 3, 12, 14, 33, 36, and 41.

In order to determine the duration of great rain-falls, I selected all those cases in which any of the rain-falls mentioned in the table on page 2, were followed by at least four inches of rain (total amount at the eighty stations) during a succeeding period of eight hours. The following table shows the result of this comparison.

Heavy Rain (four inches aggregate in eight hours) continuing more than eight hours.

Date.	Total rain-fall.	Station of greatest rain.	Date.	Total rain.	Station.	Date.	Total rain.	Station.	Date.	Total rain.	Station.	Date.	Total rain.	Station.	Date.	Total rain.	Station.
1872.																	
Sept. 11.3	10·76	Marquette.[1]	12.1	4·02	Grand Haven[2]	12.2	9·93	Saugeen.[3]									
Oct. 6.3	8·75	Vicksburg.	7.1	5·91	Pittsburg.	7.2	8·58	Montreal.	7.3	6·05	Norfolk.						
22.3	8·30	Jacksonville.[1]	23.1	9·34	Jacksonville.[2]	23.2	4·45	Charleston.[3]									
25.1	8·91	Norfolk.[1]	25.2	7·09	New York.[2]	25.3	5·03	Pittsburg.[3]	26.1	8·80	Philadelphia.[4]	26.2	5·77	Mt.Wash'ton.[5]			
Nov. 6.3	9·91	Montgomery.	7.1	13·52	New York.[1]	7.2	6·27	New London.[2]									
Dec. 20.1	14·49	New York.[1]	20.2	5·31	Boston.[2]												
26.1	9·46	Norfolk.[1]	26.2	6·10	Philadelphia.[2]												
1873.																	
Jan. 2.2	9·12	Keokuk.	2.3	6·37	Port Stanley.[1]	3.1	8·63	New York.[2]									
5.1	12·74	Lake City.	5.2	16·25	Philadelphia.												
16.1	10·08	New Orleans.	16.2	6·23	Detroit.	16.3	4·95	Lynchburg.[1]	17.1	8·05	Philadelphia.[2]						
Feb. 16.1	10·57	Louisville.[1]	16.2	9·87	Cape May.[3]												
Mar. 29.1	10·65	Lake City.	29.2	10·48	Oswego.[1]	29.3	5·80	Rochester.[2]									
April 8.1	8·70	Indianapolis.[1]	8.2	8·57	St. Louis.[2]	8.3	4·48	Nashville.[3]									
May 1.2	9·37	Montgomery.	1.3	7·95	New Orleans.	2.1	11·78	Wilmington.[1]	2.2	8·49	Wilmington.[2]	2.3	4·46	Boston.	3.1	4·58	Pittsburg.
8.1	8·33	Lynchburg.[1]	8.2	7·14	Washington.[2]	8.3	4·89	Cape May.[3]	9.1	7·88	Indianola.	9.2	7·98	New London.	9.3	4·44	Grand Haven.
June 30.2	9·23	Port Stanley.[1]	30.3	5·23	Oswego.[2]	1.1	4·95	Denver.									
July 27.2	9·63	Washington.[1]	27.3	7·31	Philadelphia.[2]												
Aug. 13.1	9·52	Philadelphia.[1]	13.2	8·27	Philadelphia.[2]	13.3	7.81	Baltimore.[3]	14.1	7.42	Breckenridge.	14.2	5·89	Boston.[1]	14.3	4·61	Portland,[2] Me.
21.1	9·56	Galveston.[1]	21.2	7·06	Mobile.[2]										[15.1	4·25	Denver.
Sept. 19.2	11·39	Cape May.[1]	19.3	8·96	Mt.Wash'ton.[2]	20.1	6·32	Wilmington.									
28.1	8·69	Fort Gibson.[1]	28.2	6·28	Fort Gibson.[2]	28.3	4·27	Chicago.[1]	29.1	7·65	Alpena.[2]						
Oct. 19.3	9·82	New London.[1]	20.1	17·65	Philadelphia.[2]	20.2	12·27	Rochester.[3]	20.3	9·86	Buffalo.[4]	21.1	5.90	Cleveland.[5]			
27.1	8·30	Knoxville.	27.2	8·68	Cape May.												
Nov. 8.1	8·64	Boston.[1]	8.2	5·09	Eastport.[2]												
18.1	8·23	Boston.	18.2	9·23	Sydney.												
24.1	11·16	Nashville.	24.2	14·69	New London.												

We thus see that in a period of fifteen months there were twenty-six cases in which a total rain-fall of eight inches in eight hours was followed by a total rain-fall of more than four inches in the next eight hours; there were sixteen cases in which it was followed by a similar rain-fall for a third period of eight hours; there were eight cases of a fourth period of eight hours; five cases of a fifth period; three cases of a sixth period; and one case of a seventh period of eight hours. These rain-areas which succeeded each other in order of time, were not, however, in all cases apparently connected with each other; that is, they were not continuous rain-areas, or even adjacent to each other. Those cases which were apparently thus connected, I have indicated by the numerals 1, 2, 3, etc., attached to the names of the stations. It must not be inferred that these rain-areas had in all cases a proper movement of translation in the direction of the stations here indicated. In some cases this apparent movement resulted from a slight increase of precipitation in one part of an extensive rain-area, and a decrease in some other part. This remark will probably explain two or three of the cases in which the apparent movement of the rain-area was from east to west. In one case however, viz: October 19th, 1873, the rain-area did unquestionably advance westward for forty-eight hours as shown on page 4. The average rate of motion of the rain-areas indicated by numerals in the table, is 20·7 miles per hour.

This table shows that great rain-areas are seldom of long continuance. In twenty-three cases the same rain-area continued for at least two periods of eight hours; in seven cases it continued for at least three periods; and in only two cases did it continue for more than three periods, that is, twenty-four hours. We thus see that rain-areas with a total rain-fall of at least four inches in eight hours, for eighty stations, seldom continue for more than twenty-four hours, only two or three such cases occurring in the United States during a year. This fact seems to indicate that the causes which produce rain, instead of deriving increased force from the rain-fall, rapidly expend themselves and become exhausted. This fact cannot be explained by supposing that the vapor of the air has all been precipitated, because these cases chiefly occur near the Atlantic coast, where the wind which supplies the vapor comes from the ocean, and the supply is therefore inexhaustible. The facts seem rather to indicate that the forces which impart that movement to the air which is requisite to a precipitation of its vapor, become exhausted after a few hours exercise.

Of the fifty-five cases included in the table on p. 2, in twenty-seven cases the place of greatest rain-fall was on the Atlantic coast. But only one-fifth of all the stations are on

the Atlantic coast; that is, the center of great rain-areas is found near the Atlantic coast *four times* as frequently as it is in the other portions of the United States. The center of great rain-areas is not found in the neighborhood of the great Lakes more frequently than it is at inland stations quite distant from the Lakes.

The distribution of these fifty-five cases by seasons was as follows:

Spring 8; Summer 9; Autumn 10 and 16; Winter 12;

showing a slight predominance of great rain-areas in autumn and winter. In my last paper it was shown that excessive rains at single stations were most common during the warmest months; but it appears that very extensive rain-falls are most common during the cooler months.

The distribution of these cases according to the hour of the day was as follows:

7.35 A. M. 25 cases; 4.35 P. M. 22 cases; 11 P. M. 8 cases.

After correcting these numbers for the inequality of the time intervals, we still find that from 4.35 to 11 P. M. great rain-falls are *not half as frequent* as during the remainder of the day. This result is quite similar to that found in my last paper with regard to great rain-falls at single stations south of latitude 36°. It is essential to the accuracy of this conclusion that the record in each case should show the actual rain-fall since the preceding observation. There are a few cases in which the last column of the record reports *heavy rain*, but the rain-column makes no mention of rain. It is presumed that generally in these cases the rain had but recently commenced, and the observer thought it would be equally satisfactory to report the entire rain-fall at the time of the next observation. There seems no reason to question the conclusion which these numbers indicate, viz: that the causes which produce excessive rain-falls in the United States, act with less intensity in the evening than during the remainder of the day.

Areas of low pressure without rain.

In order to compare the influence of a very small rain-fall with that of a very great rain-fall, I selected all those cases during a period of fifteen months (September, 1872 to November, 1873) in which the rain-fall did not amount to one-tenth of an inch in eight hours at any of the stations. The following table exhibits these cases. Column 1st contains the number of reference; column 2nd shows the day and hour of observation; column 3d shows the total rain-fall for the preceding eight hours at all the stations. In September, 1872, the num-

Rain-fall less than one-tenth of an inch in eight hours at any station.

No.	Date.	Total rain-fall.	Low Bar.	Station.	Low moved Direction.	Vel.	Rain in Low.	High Bar.	Station.
	1872.								
1	Sept. 2.3	0·04	29·65	Fort Sully.	*	0	0·00	30·25	Marquette.
2	3.1	·06	·67	Fort Sully.	East.	4	·01	·26	Escanaba.
3	14.2	·02	·71	Fort Sully.	East.	22	·00	·30	Saugeen.
4	14.3	·02	·66	Fort Sully.	East.	6	·00	·29	Toronto.
5	15.1	·06	·84	Duluth.	East.	28	·00	·35	Kingston.
6	20.3	·04	·63	Leavenworth.	N. 41 E.	15	·00	·23	Augusta.
7	21.3	·07	·77	Chicago.	*	0	·04	·22	Wilmington.
8	Oct. 1.2	·33	·67	Fort Sully.	N. 69 E.	24	·00	·22	Nashville.
9	1.3	·07	·86	Duluth.	N. 69 E.	24	·00	·27	Nashville.
10	4.2	·12	·68	Keokuk.	East.	7	·03	·07	Jacksonville.
11	5.1	·14	·82	Escanaba.	N. 18 E.	22	·05	·35	Portland, Me.
12	8.3	·13	·71	Marquette.	East.	17	·00	·21	Lynchburgh.
13	11.2	·04	·82	Fort Sully.	?	?	·00	·30	Cincinnati.
14	11.3	·00	·82	Duluth.	East.	15	·00	·30	Cincinnati.
15	12.1	·00	·71	Marquette.	East.	17	·00	·30	Lynchburgh.
16	12.2	·10	·69	Alpena.	S. 67 E.	24	·01	·15	Portland, Me.
17	14.3	·08	·59	Breckenridge.	N. 62 E.	42	·00	·24	Vicksburg.
18	15.1	·05	·49	Escanaba.	S. 68 E.	33	·05	·24	Knoxville.
19	15.2	·29	·47	Grand Haven.	S. 36 E.	30	·29	·15	Savannah.
20	15.3	·24	·53	Saugeen.	N. 86 E.	29	·24	·21	Augusta.
21	16.3	·08	·83	Fort Sully.	N. 82 E.	47	·00	·34	Philadelphia.
22	19.3	·03	·86	Omaha.	N. 54 E.	5	·00	·27	Cincinnati.
23	20.1	·00	·80	Omaha.	N. 52 E.	4	·00	·32	Nashville.
24	20.2	·00	·60	Breckenridge.	N. 47 E.	5	·00	·25	Norfolk.
25	20.3	·01	·58	Marquette.	N. 55 E.	45	·00	·27	Norfolk.
26	21.1	·07	·62	Escanaba.	S. 77 E.	15	·00	·32	Norfolk.
27	21.2	·10	·77	Milwaukee.	S. 16 E.	11	·00	·28	Norfolk.
28	31.2	·00	·77	Escanaba.	East.	?	·00	·24	Nashville.
29	Nov. 15.2	·39	·59	Quebec.	East.	?	·23	·67	Fort Benton.
30	15.3	·28	·75	Quebec.	East.	?	·15	·58	Fort Benton.
31	16.3	·16	·96	Quebec.	East.	?	·02	·65	Nashville.
32	17.3	·06	30·11	Alpena.	East.	?	·00	·71	Leavenworth.
33	21.1	·07	29·69	St. Paul.	S. 58 E.	36	·05	·44	Lynchburgh.
34	21.2	·05	·73	Alpena.	East.	35	·05	·30	Cape May.
35	21.3	·09	·76	Escanaba.	East.	6	·06	·24	Lynchburgh.
36	23.2	·10	·70	Denver.	S. 32 E.	15	·00	·42	Mobile.
37	27.3	·02	·91	Quebec.	East.	?	·02	·64	Breckenridge.
38	28.1	·00	30·09	Escanaba.	?	?	·00	·71	Breckenridge.
39	30.3	·17	29·32	Pembina.	East.	18	·16	·36	Jacksonville.
40	Dec. 3.3	·18	·99	Fort Sully.	East.	10	·00	·47	Nashville.
41	4.1	·11	·94	Fort Sully.	East.	14	·00	·51	Nashville.
42	4.2	·07	30·03	St. Paul.	S. 86 E.	42	·00	·38	Cincinnati.
43	6.2	·13	·04	Fort Sully.	East.	?	·00	·45	Davenport.
44	6.3	·04	·00	Fort Sully.	East.	?	·00	·41	Davenport.
45	7.1	·09	29·67	Pembina.	N. 49 E.	31	·05	·39	Memphis.
46	14.2	·11	·59	Milwaukee.	N. 73 E.	48	·06	·47	Breckenridge.
47	14.3	·22	·73	Alpena.	N. 69 E.	37	·12	·44	Omaha.
48	31.3	·43	·67	Santa Fe.	East.	14	·01	·43	Davenport.
	1873.								
49	Jan. 10.2	·13	·82	Montreal.	East.	?	·00	·62	Memphis.
50	11.3	·08	·55	Fort Sully.	S. 74 E.	15	·08	·57	Augusta.

Table continued.

No.	Date.	Total rain-fall.	Low Bar.	Station.	Low moved Direction.	Vel.	Rain in Low.	High Bar.	Station.
	1873.								
51	Jan. 12.3	0·10	29·73	Milwaukee.	S. 88 E.	50	0·08	30·56	Boston.
52	19.2	·39	·43	Fort Garry.	S. 72 E.	13	·07	·28	Mobile.
53	19.3	·20	·41	Fort Garry.	S. 81 E.	14	·13	·27	Mobile.
54	Feb. 1.1	·19	·65	San Francisco.	East.	18	·00	·95	Fort Sully.
55	1.3	·07	·67	San Francisco.	East.	13	·02	·74	Davenport.
56	9.1	·33	·57	Quebec.	East.	?	·11	·51	Vicksburg.
57	10.1	·08	·50	Fort Garry.	East.	27	·00	·50	Washington.
58	10.2	·08	·43	Escanaba.	East.	36	·06	·41	Savannah.
59	17.3	·10	·38	Omaha.	N. 76 E.	46	·10	·29	Oswego.
60	23.2	·32	·63	Corinne.	?	?	·00	·24	Fort Sully.
61	25.2	·25	·32	Denver.	S. 62 E.	14	·10	·16	Chicago.
62	28.2	·32	·77	Cheyenne.	East.	5	·11	·38	Cleveland.
63	Mar. 5.2	·10	·51	Virginia City.	East.	?	·08	·66	Kingston.
64	5.3	·00	·42	Virginia City.	East.	?	·00	·72	Baltimore.
65	6.1	·03	·45	Fort Benton.	East.	?	·02	·78	Lynchburgh.
66	13.1	·02	·92	Fort Benton.	?	?	·00	·42	Nashville.
67	13.2	·03	·58	Virginia City.	East.	20	·01	·33	Savannah.
68	13.3	·02	·79	Corinne.	East.	20	·00	·40	Savannah.
69	16.3	·04	·68	Santa Fe.	East.	7	·03	·40	Cincinnati.
70	22.2	·10	·64	Omaha.	East.	32	·00	·30	Fort Sully.
71	22.3	·01	·66	Marquette.	East.	32	·00	·47	Fort Sully.
72	27.3	·05	·41	Omaha.	S. 50 E.	42	·00	·36	Norfolk.
73	April 4.1	·08	·31	Yankton.	East.	7	·03	·26	Kingston.
74	4.3	·05	·50	Leavenworth.	East.	5	·01	·36	Kingston.
75	21.2	·08	·45	Leavenworth.	S. 29 E.	29	·00	·26	San Francisco.
76	May 16.1	·09	·58	Santa Fe.	?	?	·07	·16	Duluth.
77	June 20.2	·23	·60	Fort Sully.	?	?	·00	·13	Mobile.
78	July 6.3	·04	·78	Omaha.	East.	5	·00	·12	Denver.
79	12.3	·12	·48	Breckenridge.	S. 50 E.	13	·10	·29	New London.
80	21.3	·17	·39	Fort Garry.	N. 39 E.	9	·02	·19	Lynchburgh.
81	Sept. 11.3	·09	·62	Marquette.	East.	7	·02	·29	Fort Benton.
82	21.1	·30	·76	Fort Garry.	East.	13	·04	·34	Washington.
83	Oct. 2.2	·06	·79	Havannah.	?	?	·01	·27	Marquette.
84	2.3	·06	·83	Havannah.	?	?	·00	·32	Marquette.
85	9.2	·00	·49	Fort Garry.	?	?	·00	·34	Chatham.
86	9.3	·08	·58	Fort Garry.	East.	?	·02	·36	Chatham.
87	10.2	·04	·68	Fort Garry.	?	?	·00	·35	Corinne.
88	10.3	·02	·86	Duluth.	East.	?	·00	·34	Cheyenne.
89	12.3	·23	·51	Fort Garry.	East.	19	·00	·39	Portland, Or.
90	13.3	·15	·87	Alpena.	East.	?	·00	·31	Wilmington.
91	14.2	·11	·66	Yankton.	N. 71 E.	25	·01	·34	Wilmington.
92	14.3	·02	·72	Fort Sully.	N. 71 E.	6	·02	·44	Saugeen.
93	15.3	·03	·95	St. Paul.	East.	20	·00	·52	Cape May.
94	30.1	·30	·71	Duluth.	S. 69 E.	27	·21	·48	Philadelphia.
95	Nov. 9.3	·16	·38	Cape Rozier.	?	?	·02	·36	Corinne.
96	10.1	·02	·48	Farther Point.	?	?	·00	·38	Corinne.
97	10.2	·09	·87	Fort Sully.	?	?	·00	·34	Corinne.
98	13.3	·18	·61	Virginia City.	N. 77 E.	25	·00	·23	Portland, Or.
99	14.1	·17	·43	Fort Garry.	N. 77 E.	25	·00	·36	Portland, Or.
100	14.2	·17	·41	Fort Garry.	N. 77 E.	25	·09	·34	Portland, Or.
101	16.1	·11	·33	Oswego.	S. 79 E.	29	·11	·46	Corinne.

ber of stations was seventy-two, but this number was gradually increased and in November, 1873, amounted to eighty-eight. Column 4th shows the height of the barometer at the nearest center of minimum pressure; column 5th shows the station at which the pressure given in column 4th was observed; column 6th shows the direction in which the low center had moved during the last eight hours, and column 7th shows the velocity with which it moved expressed in miles per hour. Column 8th shows the total amount of rain observed within the area of low barometer; that is, at the stations where the pressure was less than thirty inches. Frequently there was at the same time a second center of low pressure near the borders of the United States, but columns 4–8 refer exclusively to the first center; column 9th shows the height of the barometer at the center of maximum pressure, and column 10th shows the station at which this high pressure was observed. Frequently there was at the same time more than one center of high pressure within the limits of the United States, but columns 9 and 10 refer to that which was regarded as the principal center.

This table shows that barometric minima frequently occur with very little rain. Of the 101 cases here mentioned, more than half showed a pressure less than 29·70; more than one-third were below 29·60, and nearly one-quarter of the cases were below 29·50. The average pressure at the stations of greatest rain-fall mentioned in the table on page 2, was 29·74, and the average pressure at the center of the low barometer attending these remarkable rain-falls was 29·47.

It may be urged that these cases of minimum pressure generally occurred in that region where the stations of observation were widely separated, and that rain may have occurred at intermediate points where there was no observer. There is, however, a considerable number of cases in which the area of low barometer included a large number of stations. In about half of the cases there were at least twenty stations which showed a pressure below thirty inches; in one-third of the cases there were at least thirty stations which showed a pressure below thirty inches; and in several cases there were over fifty stations which showed a pressure below thirty inches. The following table contains the most important examples. Column 1st shows the number of reference from the preceding table and column 2nd shows the number of stations at which the barometer was below thirty inches.

There seems to be no room for doubt that barometric minima sometimes form with little or no rain, and continue without any considerable rain for eight hours, and sometimes for twenty-four hours or longer. These barometric minima seldom continue stationary for eight hours, but almost invariably

Number of stations within the area of low barometer.

No.	Stations	No.	Stations	No.	Stations	No.	Stations	No.	Stations	No.	Stations
75	70	60	47	35	43	74	39	16	32	59	30
101	67	39	45	7	43	100	39	24	31	61	30
77	58	70	45	17	42	58	35	36	31	90	30
19	53	53	44	18	42	73	34	11	30		
76	51	34	44	10	41	39	34	27	30		
20	48	52	43	71	39	6	33	29	30		

travel to the eastward. In several cases the center of least pressure was beyond the limits of the United States so that it is impossible to assign satisfactorily either the direction of their progress or their rate of motion. The table on pages 14 and 15 shows the best results I have been able to deduce from the observations. The average of all these directions is a little north of east, and the average velocity is 20·7 miles per hour. This direction is not quite as northerly as that given in my third paper for barometric minima generally, and the velocity is twenty per cent less.

In order to show more clearly the movement of the barometer during these periods of small rain-fall, I have represented upon Chart III the iso-baric curves for one of these periods, viz: October 19–21, 1872. The most western oval represents the isobar 29·8 for October 19th; the next curve represents the isobar 29·6 for October 20th; and the most eastern curve represents the isobar of 29·8 for October 21st; each of the curves corresponds to the 4.35 P. M. observation. It will be seen that during the first twenty-four hours, the center of least pressure moved only about five miles per hour; but during the next twenty-four hours the average motion was twenty-two miles per hour. During these forty-eight hours not a drop of rain was recorded at any station within the area of a pressure less than thirty inches, although on the 20th of October this area had a diameter of 1,500 miles.

The observations on the amount of cloudiness at the different stations confirm the observations of rain-fall. The following table presents a summary of these observations. Column 2d shows the number of stations within the area of low barometer (i. e., less than thirty inches pressure) at which the sky was reported to be entirely clear at the dates given in column 1st, except that the air was very generally reported to be *smoky* or *hazy*; column 3d shows the number of stations at which the sky was partly cloudy; and column 4th shows the number of stations at which the sky was entirely overcast.

The following are the stations at which the sky was reported to be overcast, viz: October 19.2, Virginia City and Duluth; 20.2, Corinne, Cheyenne and Duluth.; 20.3, Denver, Cheyenne

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	No clouds.	Partly cloudy.	Entirely overcast.
Oct. 19.2	5 stations.	2 stations.	2 stations.
19.3	8 "	2 "	none.
20.1	9 "	5 "	none.
20.2	13 "	7 "	3 stations.
20.3	15 "	3 "	3 "
21.1	5 "	7 "	3 "
21.2	4 "	9 "	5 "

and Duluth; 21.1, St. Paul, Duluth and Escanaba; 21.2, Santa Fe, Duluth, La Crosse, Keokuk and Toronto. Six of these cases occurred in the neighborhood of the Rocky Mountains, so remote from the center of least pressure that if there had been a rain-fall in that vicinity, it could not be supposed to be the cause of the barometric minimum under discussion. The long continuance of clouds at Duluth, and the extension of this cloud area on the 21st indicates an upward movement of the atmosphere attended with a slight precipitation of vapor, and there may have been rain-fall at places further north. But when we consider that in the Southern States a heavy rain-fall covering an area several hundred miles in diameter exerts scarcely any appreciable influence on the barometer, we cannot suppose that the very limited rain-fall which may possibly have occurred from October 19th to the 21st had any sensible influence in the production of the barometric minimum, or in causing its eastern progress, so that it seems safe to conclude that *rain-fall is not essential to the formation of areas of low barometer, and is not the principal cause of their formation or of their progressive motion.*

The barometric minimum October 19th, appears to have resulted from an area of high barometer (30·35) in the neighborhood of the Ohio valley combined with an area of high barometer (30·29) in Oregon. This excess of barometric pressure on opposite sides caused a general movement of the intermediate atmosphere towards the valley of the upper Missouri, and each of these currents being deflected to the right by the earth's rotation the result was a diminution of pressure over the region between the Rocky Mountains and Lake Superior. These two areas of high barometer on opposite sides of the low area were remarkably persistent from October 19th to 21st, but advanced eastward at about the same rate as the barometric minimum. Plate III, shows the direction of the winds October 20th, 4.35 P. M. They indicate a decided inward movement of the air and a circulation about the center of low pressure. At several of the stations the winds were uncommonly strong. The following table shows the direction and force of the wind where the velocity was greatest.

	Direction.	Velocity.		Direction.	Velocity.
Fort Sully	N.W.	36 miles.	Davenport	S.W.	18 miles.
Duluth	N.E.	28 "	Leavenworth	S.	18 "
Chicago	S.	23 "	Escanaba	S.E.	16 "
Grand Haven	S.	19 "	Omaha	S.	16 "

The distribution of the cases of small rain-fall mentioned in the table on pages 14 and 15, according to the seasons of the year, is as follows:

Spring, 14 cases. Summer, 4 cases.
Autumn, 39 and 21 cases. Winter, 23 cases.

We see that these cases occur most frequently in the autumn and especially in the month of October. They are generally accompanied by a hazy or smoky condition of the atmosphere, and this is the phenomenon which is generally known under the name of *Indian Summer.* It appears to be due to an uncommonly tranquil condition of the atmosphere extending entirely across the continent; and similar cases frequently occur in each month of the year from September to March, but are most common in October.

A comparison of all the facts which have been presented in this paper, together with my six former papers, appears to warrant the following generalizations.

1. Areas of low barometer result from a general movement of the atmosphere towards a central area, and this movement is accompanied by a deflection of the wind to the right, which causes a tendency to circulate around the center with a motion spirally inward.

2. This deflection to the right, which results from the earth's rotation, causes a diminished pressure within the area of this inward movement, and the pressure is still further diminished by the centrifugal force resulting from the circulation about a center.

3. The amount of the barometric depression depends upon the force of the wind, and the geographical extent of the revolving atmosphere. The effect of centrifugal force is not considerable except when the velocity of the wind approaches that of a hurricane. With a velocity of 100 miles per hour, the depression due to centrifugal force may amount to about two inches; but in the winter storms of the middle latitudes with a velocity not exceeding forty miles per hour, the depression due to centrifugal force seldom exceeds one or two-tenths of an inch. In these storms, three-quarters of the observed depression of the barometer is usually the effect of the earth's rotation; but in order that the depression at the center may amount to as much as one inch, it is generally necessary that this system of circulating winds should prevail over an area nearly 2,000 miles in diameter.

4. In North America, south of latitude 35°, areas of low pressure are less frequent and generally exhibit a less depression than near latitude 45°, because the area over which a cyclonic movement of the winds prevails is small; and this area is small because if a cyclonic area could be formed having a radius of 1,000 miles with its center in latitude 30°, its circumference must extend southward to latitude 16°, where the trade winds are steady and seldom interrupted. Such a diversion of the winds toward the north, even if it could be produced, could not be long maintained; so that a large cyclonic area with its center in latitude 30° is well nigh impossible; and it is impossible that there should be a great depression of the barometer in latitude 30°, except with a wind having a hurricane velocity. This is believed to be the reason why in North America the centers of great storms are generally found north of latitude 40°.

5. The causes which may produce a general movement of the atmosphere toward a central area are (A) unequal pressure as shown by the barometer; (B) unequal temperature; and (C) unequal amount of aqueous vapor. Of these three causes the effect of the first is generally so decided that the influence of the other two causes can only be detected by careful observation; but when the pressure of the air is nearly uniform over a large extent of country, the influence of the other two causes is sometimes very palpable, and their influence is generally seen in a slight deflection of the winds from the direction they would have if wholly controlled by the first cause. I have made a considerable collection of facts illustrating the influence of temperature upon the direction of the winds, which I intend to publish hereafter.

6. A cyclonic movement of a large mass of air is generally attended by an upward motion in certain localities, chiefly on the eastern side of the center of low pressure, and this upward movement results in rain-fall. The rain-fall is then not generally the original cause of the barometric depression, but rather an incident of the cycloidal movement of the atmosphere. The fall of the barometer during a rain storm cannot be ascribed to the simple condensation of the vapor of the atmosphere, as some have supposed, since a rain-fall of one or two inches prevailing over an area 300 miles in diameter near latitude 30° produces scarcely an appreciable effect upon the barometer. See tables on pages 2 and 3.

7. The progress of areas of low barometer in all latitudes is determined mainly by the same causes which determine the general system of circulation of the atmosphere; and their normal direction is changed by whatever causes may change the direction of the winds.

8. The heat which is liberated in the condensation of a large amount of aqueous vapor must exert an influence upon the movements of the air, so that while the rain is generally to be regarded not as the original cause but rather as one of the incidents of extensive cycloidal movement, if the rain-area has great geographical extent, it may have a decided influence upon the amount of the barometric depression and upon the velocity with which the storm advances; sometimes accelerating its motion, sometimes retarding it, and sometimes holding it nearly stationary in position for two or three days. In my former papers I have presented some facts which seem to authorize these statements, and I am collecting additional facts bearing upon the same question.

It may be thought that these generalizations present nothing original or novel, but several of them are disputed by meteorologists who have given no little attention to the subject.

In preparing the materials for this article I have been assisted by Mr. Edward S. Cowles, Ph.D., a graduate of Yale College of the class of 1873.

Art. II.—*The Germination of the genus* Megarrhiza, Torr.; by Asa Gray.

The object of this brief communication is to describe a peculiar structure which *Megarrhiza Californica* exhibits in germination, and to call for observations upon other species, at the time of germination, in the hope of thereby extending our present imperfect knowledge of this genus of big-rooted *Cucurbitaceæ* of our Pacific coast. For the extraordinary peculiarity in question, being one which, in other cases, is known to exhibit itself in certain species of a genus (as in *Anemone* and *Delphinium*), and not in others, so it may in the present genus give aid in distinguishing the five species which have been characterized upon more or less incomplete or scanty materials.

The first species known was from Oregon; the specimens, being in flower only, were referred in Hooker's Flora Borealis Americana, i, 220, to *Sicyos angulatus*, but were separated in Torrey and Gray's Flora of North America, i, 542, under the name of *Sicyos Oreganus*. In the course of time it was found that there was a similar if not identical species in California, and apparently more than one, that they were perennial from very large and fleshy roots, that, while the flowers much resemble those of *Echinocystis*, the seeds were turgid, marginless, and with thick and fleshy cotyledons. Dr. Torrey, upon whom the examination of these plants devolved, many

(about thirty) years ago proposed for them the generic name of *Megarrhiza;* but he refrained from publishing it, even omitted all mention of it in his account of Dr. Bigelow's excellent collection made in Whipple's Expedition (Pacif. R. Rep. iv, 1857), although good materials of that and other collections were in his hands, because he could not make up his mind whether he had to do with one variable species or with two or three. But in the sixth volume of the Pacif. Railroad Rep., which bears the same date of 1857, in Dr. Newberry's list of plants collected in Williamson's Expedition (p. 74), two species are enumerated, thus:

"*Megarrhiza Californica*, Torrey. Petaluma and Sonoma, California; April, in flower."

"*Megarrhiza Oregana*, Torrey. On the shores of Klamath Lake and banks of Willamette River, O. T.; August and September, in fruit."

Before this, however, viz: in March, 1855, Dr. Kellogg, of San Francisco, communicated to the California Academy of Natural Sciences (Proc. Calif. Acad., i, 38), an account of one of these species, apparently the second, under the name of *Marah muricatus.*

A few years later, some plants having been raised in France from Californian seeds, M. Naudin (in Ann. Sci. Nat., ser. 4, xii, 154, t. 9, under date of 1859, but, as the letter-press shows, not printed until 1860 or 1861), published the plant which Dr. Torrey had called *M. Californica* under the name of *Echinocystis fabacea.* This extension of *Echinocystis* was adopted by Bentham and Hooker in their Genera Plantarum. It was, moreover, anticipated by Dr. Kellogg, who, in a second communication to the Californian Academy, under date of June 4, 1855, re-describes his former *Marah muricatus*, states that it "legitimately belongs to *Echinocystis*," and gives it the name of *E. muricatus.* When, shortly after Dr. Torrey's death, I superintended the printing of his account of the plants collected on our Pacific coast in Wilkes' Expedition, I found that he had left the article on this genus unwritten, and apparently had not determined either upon the number of the species or upon the distinctness of his proposed genus.

When in the recent preparation of the Botany of California the subject came to be studied anew by Mr. Watson, with the aid of more extensive materials, and when these materials were found to exhibit such diversities that at least five species had to be recognized (Bot. California, i, 240), with notable differences in ovary, fruit, seeds, etc., but no approximation to the eastern *Echinocystis*, it could hardly be doubted that Torrey's genus ought to be reinstated; and this was accordingly done.

The *M. Californica* had been raised in the Botanic Garden of Harvard University many years ago, but I had not seen the

germination; and we were never able to bring the plant into blossom, as it invariably died down to the ground soon after making a moderate growth. On germinating some fresh seeds early this spring, I was somewhat surprised to find that they came up in the manner of beans. Instead of remaining hypogæous, as from the great thickness of the cotyledons would have been expected, the body of the seed in its shell was raised well out of the soil upon what seemed to be a well developed radicle, like that of *Echinocystis*. If the cotyledons had expanded, though remaining fleshy, in the manner of *Phaseolus*, the difference between this and *Echinocystis*, with cotyledons truly foliaceous in germination, would be much less than had been supposed. I waited long to see if this would occur; I also waited in vain for the expected development of the plumule from between the bases of the fleshy cotyledons. After the lapse of about a fortnight, the plumule in all three of my germinating plantlets came separately out of the soil of the pot; and, on exposing the whole to view, the state of things represented in fig. 1 came to view. That is, the plumule came forth from the base of what appeared to be an elongated radicle (of two or three inches in length); and below this the thickening of the root, which acquires enormous dimensions in old plants, had already commenced. A large amount of the nourishing matter stored in the cotyledons had been carried down to the root and used in its growth as well as that of the plumule. The latter came from a cleft at the very base of the seeming radicle, which otherwise appeared to be solid. But on cutting it across toward the base this was found to be tubular, as shown at the bottom of fig. 2; and later, when more spent and beginning to wither, this stalk was separable from above downward into two, as shown in the upper part of the same figure.

1.

This, therefore, is a case in which long petioles to the cotyledons (of which there is no appearance in the seed), connate into one body, are developed and greatly lengthened in place of the radicle, which is thus simulated. It is the same as in *Delphinium nudicaule* of California, and some other species; only in that genus the cotyledons expand and become foliaceous. In the horse-chestnut petioles are also developed to the cotyledons to a moderate extent, but without union, (see Gray's First Lessons, fig. 24), thus pushing the radicle and plumule well out of the firm seed-coat, in which the very heavy and fleshy cotyledons remain; and the radicle itself, as in the pea, does not further lengthen. In *Ipomœa leptophylla* the radicle remains in like manner short, while petioles to the (here foliaceous) cotyledons develope to a great length, bringing these separately out of the ground, and the plumule between follows later.

2.

Botanists on the Pacific coast are earnestly requested to examine the germination of all the species of *Megarrhiza*, and to compare them with the figures and description here given. At least three species should be met with near San Francisco, and in neighboring parts of California. According to the characters assigned by Mr. Watson in the Botany of California, *M. Californica* should be known by its obovoid seeds, of less than an inch in length, with a small hilum at the narrow base: *M. Marah*, by its more numerous seeds horizontally imposed in a large fruit (of four inches in length), each seed roundish and depressed, flattened, an inch in diameter and about half as thick, with a prominent lateral hilum. *M. muricata*, by a nearly naked fruit only an inch in diameter, containing only two globose seeds of half an inch in diameter. *M. Oregana*, which is known to occur from the Columbia River to the north of California, appears to have seeds resembling those of *M. Marah*, but rather smaller; but they are not well known. The remaining one, *M. Guadalupensis*, of Guadalupe Island, off Lower California, is much out of ordinary reach, unless it should be found in the southern part of the State.

Mature fruits and seeds of all the species are much desired.

Fig. 1 represents a germinating plantlet of *Megarrhiza Californica*, of natural size, complete except the lower part of the root. Fig. 2 represents the cotyledons at a later period, with their united petioles separated from above, still united into a tube below, the lower end of which is cut away.

ART. III.—*On the absorption of Bases by the Soil;* by H. P. ARMSBY.

THE question of the nature of the absorptive power of the soil for bases may be regarded as still to a certain extent an open one. Although the researches of Henneberg & Stohmann, Peters, Weinhold and others have shown conclusively that the absorption is accompanied by a chemical reaction between the salt whose base is absorbed and the soil, an equivalent quantity of other bases being dissolved; and though the investigations of Way, Eichhorn, Rantenberg, Heiden, Knop and Mulder have as conclusively connected this reaction with the presence in the soil of certain zeolitic silicates which appear to be the agents of absorption; it has been the opinion of many distinguished authorities, e. g., Liebig, Brustlein, Henneberg & Stohmann, that the prime cause of absorption is physical in its nature.

The fact which more than any other has served to sustain this view is the peculiar effect of the concentration and volume of the solution upon the amount of absorption. As is well known a given weight of soil absorbs a greater amount of a base from a concentrated than from a dilute solution, and more from a large than a small bulk of the same solution, though the variation is in neither case proportional. This, it is considered, is proof that absorption is at least in part due to physical and not chemical force.

This force seems generally to have been assumed to be analogous to the surface-attraction exhibited by charcoal and other porous bodies. Peters and others hold that the physical force is the prime cause, and that the chemical phenomena are only secondary, while others believe that chemical action is the prime cause and is modified by physical force. Knop advances the theory (Bonitirung der Ackererde, pp. 39 and 152, Fres. Zeit., xiv, 246) that the soil has the power of *dissociating* salts in the presence of some substance like calcium carbonate which can unite with the acid, and that then the chemical union of the base follows.

Pillitz (Fres. Zeit., xiv, 55 and 282) has indeed found that, if a large volume of solution be filtered through a soil until no further absorption takes place, the absorption is proportional to the amount of soil, and that at a certain concentration of the solution the absorption reaches a maximum above which it cannot be raised. He concludes from this that the objections to the chemical view based on the variability of absorption are removed, since in his experiments the absorption was constant.

But these facts, however interesting and important, neither

do away with the variability of absorption as ordinarily determined nor rob that variability of its force as an argument for the physical nature of absorption, since as Pillitz himself says even the most dilute solution is not exhausted, which must be the case were the variations due simply to a lack of sufficient material to saturate the soil.

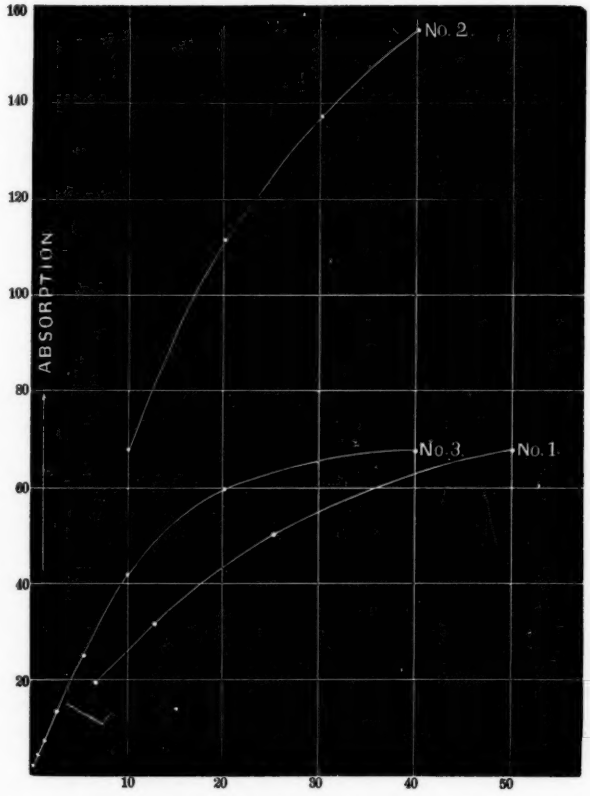
In view of the interest attaching to this question it seemed to me desirable to compare the behavior of the soil in this respect with that of pure hydrous silicates. If it should be found that the exchange of bases between these compounds and neutral salts showed the same variations as soil-absorption, then, whatever view might be held as to the cause of these variations, all possible objections to the theory which considers soil-absorption to be such an exchange of bases between the salt and the hydrous silicates known to exist in the soil would seem to be removed.

As illustrating the variations of soil-absorption the following determinations made in the laboratory of Prof. Knop in Leipzig may be adduced. Two soils were used: No. 1, Deposit of the Nile. No. 2, A loamy soil from the vicinity of Leipzig.

The absorptive power of these soils for ammonia was determined by Knop's method (Bonitirung der Ackererde, 49) by digesting the soil in the cold with a solution of NH_4Cl of known strength for forty-eight hours and determining the ammonia remaining in the fluid by means of the azotometer. The results denote the c. c. of nitrogen at 0° C. and 760 m.m. pressure contained in the ammonia absorbed, and the concentration of the solution employed is stated in the same way. It was found more convenient to vary the amount of the soil than of the solution.

	Nos.	N in 1 c. c. of Sol.	Wt. of Soil.	Absorption. Soil No. 1.	Soil No. 2.
I.	1.	1·079 c. c.	50 grms.	67·7 c. c.	45·2 c. c.
	2.	----	25 "	49·6 "	28·4 "
	3.	----	12·5 "	31·5 "	16·2 "
	4.	----	6·25 "	18·4 "	9·3 "
II.	1.	2·158 "	50 "	111·9 "	67·3 "
	2.	----	25 "	77·7 "	38·2 "
	3.	----	12·5 "	52·2 "	20·3 "
	4.	----	6·25 "	33·1 "	12·7 "
III.	1.	3·237 "	50 "	137·8 "	
	2.	----	25 "	85·0 "	
	3.	----	12·5 "	48·8 "	
	4.	----	6·25 "	32·1 "	
IV.	1.	4·316 "	50 "	155·7 "	88·1 "
	2.	----	25 "	94·0 "	55·1 "
	3.	----	12·5 "	54·6 "	36·3 "
	4.	----	6·25 "	33·1 "	24·9 "

Representing graphically the results of the first series (I) we obtain the curve No. 1 in the figure, showing the influence of the relative volume of the solution on the absorption by soil No. 1. The other three series give exactly similar curves, and the influence of the concentration of the solution is seen in curve No. 2, which represents the absorption by fifty grams of soil No. 1 from solutions of increasing concentration.



But not only these experiments, but all others on the subject accessible to me show essentially the same result. With the exception of a single experiment by Laskowsky (Knop, Boni., etc., p. 150) the absorption never increases proportionally to the soil, nor is it, as is sometimes stated, independent of its amount.

In order to study the absorption of bases by hydrous silicates an artificial silicate was prepared in the method described by Way (Jour. Roy. Agr. Soc. of Eng., xi, 313).

Eighty grams of air dry aluminum hydrate were dissolved in a strong solution of soda (containing about 200 grams NaOH), the solution was diluted largely, and to it were added about 310 c. c. of commercial water-glass, containing 91 grms. SiO_2. A bulky, flocculent precipitate resulted which subsided readily and could be washed by decantation without much difficulty. The washing was continued till the washings showed no alkaline reaction, the precipitate collected on a filter and dried at 100° C. till it seemed dry to the touch. It was then pulverized, brought upon a filter, washed till the filtrate gave no precipitate with the solution of calcium chloride used in the experiments, and again partly dried at 100° C.

An analysis gave:—

Loss at 100° C	39·94
Dry substance	60·06
	100·00

The dry substance contains:—

SiO_2	48·42
Al_2O_3	23·16
Na_2O	14·20
H_2O	14·13
	99·91

A neutral solution of calcium chloride was also prepared by dissolving fused $CaCl_2$ in water, acidifying with HCl, and neutralizing with $CaCO_3$. 1 c. c. contained the equivalent of 0·01683 grams CaO.

Varying portions of the air-dry silicate were digested in closed flasks with the above solution diluted to five, ten, or twenty times its volume exactly as in the experiments with soil. The mixtures stood three days at ordinary temperature with frequent shaking, and then in 50 c. c. of the liquid the lime was precipitated as oxalate in the usual way, and weighed as oxide. The result calculated on the whole quantity of the solution and subtracted from the amount of lime originally present gave the absorption. The results in every case are expressed as CaO, as is also the strength of the solution employed. The following are the results.

Nos.		CaO in 1 c. c. of sol.	Wt. of silicate.	Vol. of solution.	Absorption.
V.	1.	0·003366 grms.	40 grms.	200 c. c.	*[0·6732 grms.]
	2.	------	20 "	---	0·5952 "
	3.	------	10 "	---	0·4172 "
	4.	------	5 "	---	0·2432 "
	5.	------	2·5 "	---	0·1324 "
	6.	------	1·25 "	---	0·0680 "
	7.	------	0·625 "	---	0·0328 "
	8.	------	0·3125 "	---	0·0164 "

* Only traces of lime were left in the solution.

Nos.		CaO in 1 c. c. of sol.	Wt. of silicate.	Vol. of solution.	Absorption.
VI.	3.	0·001683 grms.	10 grms.	200 c. c.	0·2996 grms.
	4.	------	5 "	---	0·2084 "
	5.	------	2·5 "	---	0·1217 "
	6.	------	1·25 "	---	0·0673 "
	7.	------	0·625 "	---	0·0338 "
	8.	------	0·3125 "	---	0·0198 "
VII.	5.	0·000841 grms.	2·5 grms.	200 c. c.	0·1151 grms.
	6.	------	1·25 "	---	0·0663 "
	7.	------	0·625 "	---	0·0359 "
	8.	------	0·3125 "	---	0·0187 "

It will be seen that the same variations occur here as in soil-absorption. Representing the results of (V) graphically, and expressing the absorption in centigrams for convenience, we obtain the curve No. 3, similar in character to No. 1.

Further these results seem to correspond with those of Pillitz already mentioned. The existence of a "point of saturation" is simply due to the fact that there is a limit to the amount of replaceable bases in the soil. A similar limit seems to have been reached in some of these experiments. In experiment VII, 8, about two-thirds of the soda of the silicate has been replaced by lime, and an increase of concentration seems unable to carry the replacement further. The same is seen in VII, 7, and the corresponding ones of the other series, while in those experiments where this limit is not reached the absorption increases with the concentration in the same way as in soil-absorption. For the same reason, apparently, the absorption in the last four experiments of (V) and the last three of VI, decreases proportionally to the soil, seemingly unable to pass this limit of two-thirds. That the rest of the soda *cannot* be displaced is not probable, but it is evidently more difficultly replaceable. The high absorption of (VI, 8) is perhaps an error of experiment.

Since, now, it has been shown that the absorption of bases by hydrous silicates resembles in all essential particulars soil-absorption there would seem to be no reason why the latter should not be considered to be due chiefly to these silicates in the soil. That other agents may also be concerned to some extent, especially in the absorption of free bases, is doubtless true, but that any form of surface-attraction can decompose simple salts is yet to be proved.

In regard to the chemical or physical nature of absorption it will hardly be denied, in view of the results of Way, Eichhorn and Heiden, that the reaction between the hydrous silicates and a salt is essentially a *chemical* process consisting in a partial exchange of bases. The reason why the exchange is not complete would seem to be the same as the reason why, e. g., HCl and O when heated together are not completely converted into H_2O and Cl, or the reverse; or why, when two salts are mixed

in solution, a partial decomposition takes place, as has been shown by Gladstone (Phil. Trans., 1855, p. 179) and others; viz: the so-called *action of mass*, or the tendency of the resulting new compounds to react on each other and re-produce the the original bodies. This tendency is specially marked when the total solubility of the system is nearly the same after and before the reaction, as where all the possible products are soluble or where one insoluble body gives rise to another.

The latter is exactly what occurs in soil-absorption, or the absorption of bases by pure silicates, and hence we may safely say that the variations caused by the volume and concentration are due to the influence of mass on a primarily chemical process.

This view has already been suggested by Ad. Mayer (Lehrbuch der Agricultur-chemie, ii, p. 93). It receives confirmation from the researches of Gladstone already alluded to. He added to a solution of ferric nitrate increasing portions of potassium sulpho-cyanate and found that each successive addition produced less and less ferric sulpho-cyanate, but that the ferric nitrate was never completely decomposed. His results represented graphically give a curve essentially like those for absorption already described.

According to this view it is the accumulation of sodium chloride in the solution which prevents the further absorption of lime by the silicate. If then sodium chloride were added to the solution in the first place, we should expect the absorption to be less. To test this (VII) was repeated with the addition of 0·1700 grms. NaCl (about equivalent to the $CaCl_2$ present) to each experiment. The following results were obtained.

Silicate.	Abs. without NaCl.	Abs. with NaCl.
2·5 grms.	0·1151 grms.	0·1039 grms.
1·25 "	0·0663 "	0·0595 "
0·625 "	0·0359 "	0·0303 "
0·3125 "	0·0187 "	0·0143 "

In every case the absorption has been decreased by the addition of the sodium chloride, as required by the theory.

We are then, I believe, justified in the following conclusions.

The absorption of combined bases by the soil consists in an exchange of bases between the salt and the hydrous silicates of the soil.

This exchange, which is primarily chemical, is only partial, its extent varying:

1st. With the concentration of the solution.

2d. With the ratio between the volume of the solution and the quantity of soil used.

The cause of these variations is probably the "action of mass," or the tendency of the resulting compounds to re-form the original bodies, the absorption actually found in any case marking the point where the two forces are in equilibrium.

Laboratory of Rutgers College, May, 1877.

ART. IV.—*Double-Star Discoveries with the 18½-inch Chicago Refractor;* by S. W. BURNHAM.

THE new double stars described below were discovered with the 18½-inch Clark refractor of the Dearborn Observatory, on the nights of October 1, 2, 4, 7, 10, 11, 15, 16, and 17, 1876, and are some of the results obtained in the use of that instrument during a period of three or four weeks, the only opportunity the writer has had of using it. The observations here given are not as complete as could be desired; some of the new pairs being only partially measured, and others not at all. A number of other new and interesting pairs were found, but the approximate readings of the circles, roughly noted at the time of finding them, are not sufficient to positively identify them in the star catalogues and thus fix their absolute places; and these with other suspected pairs, and new companions to prominent pairs and binary systems, are necessarily not included in the following list. The intention was to measure, during the course of the work, all new pairs on at least three different nights, in order to give, as accurately as possible, reliable micrometrical results with which future observations might be compared for determining the question of physical relation between members of the systems. This seemed to be the more important from the fact that many of these pairs are too difficult for ordinary apertures, and are practically beyond the reach of most of the well-known double-star observers in Europe; and a considerable time might elapse before the objects would be re-observed elsewhere. It is necessary to state, in explanation of its manifest incompleteness, that the work was unexpectedly, and without notice, terminated by the action of the officers of the Chicago Astronomical Society which has control of the instrument, and no opportunity has been afforded to complete the projected series of observations which was but just commenced. Enough is given, however, to show the value and effectiveness of the telescope in this important branch of astronomical research; and how much might be accomplished for science, if it were used for any other purpose than exhibition to visitors.

The reference numbers attached to these stars are the numbers in my double-star catalogues, seven of which lists, with the stars numbered consecutively, have appeared in the Monthly Notices of the Royal Astronomical Society, Astronomische Nachrichten, and in this Journal.

No. 437=L 4291.

R. A.=$2^h\ 12^m\ 26^s$
Decl.=$+3°\ 39'$

Not measured, but angle and distance estimated as follows:

$P=45°\pm$ $D=5''\pm$

The principal star is about $7\frac{1}{2}$ magnitude, and the companion not brighter than 11 of Struve's scale. The pair of small stars in the field, *sp* is Σ 247 *rej.*

No. 438=Σ 2538
R. A.=$19^h\ 27^m\ 3^s$
Decl.=$+36°27'$

A and B	P=43°·5	D=6″·32	(1876·8)
A and C	245·2	53·04	(1830·8)
C and D	52·5	6·07	(1830·8)

The three large stars, A, C and D, constitute the double star Σ 2538(=S 719), but the small companion near the principal star is now recorded for the first time, and is probably too minute for ordinary telescopes. The measures given above of C and D are by Struve. These stars seem, by a comparison of Struve's results with those obtained later by Mädler, Secchi and Otto Struve, to be relatively fixed, but some of the measures are not very accordant. By a single observation I found these angles respectively, 237°·1 and 51°·9, but there may be an error of 10° in reading micrometer of the first. There is still another new member of this group, in an exceedingly faint star almost exactly midway between A and C. No opportunity occurred to measure this. Struve gives the magnitudes of A, C and D as 8·2, 8·3 and 8·7 respectively.

No. 439=Arg. (29°) 3845
R. A.=$19^h\ 55^m\ 56^s$
Decl.=$+29°\ 30'$

The principal star is about the eighth magnitude (Argelander, 8·1), with a small companion. The measures of one night give:

P=249°·7 D=2″·70 (1876·8)

No. 440=L 38520
R. A=$20^h\ 1^m\ 27^s$
Decl.=$+35°\ 27'$

A and B	P=61°·3	D=6″·47	Mags. 7·0 . . 12+	(1876·8)
A and C	25·8	7·75	11·0	(1876·7)
A and D	296·0	11·27	9·5	(1783·7)
A and E	106·8	28·15	11·5	(1876·7)
A and F	32·8	29·45	7·5	(1783·7)
F and G	113·0	10·12	12·	(1876·8)

The large stars (A, D, F), of this interesting group have long been known, and constitute the double star ♅ III. 113 (=Sh 314=Σ 2630 *rej*). The small attendants, C and E, I

found with the 6-in. refractor in 1875. The faint star, G, was discovered by Mr. I. M. Ward of Belfast, widely known for his remarkable acuteness of vision, with an aperture of only 4·2-in. The very minute companion, B, was added with the 18½-in., the whole forming one of the finest multiple systems known. Of the measures given above, D and F are by Sir William Herschel; C and E by Baron Dembowski; and B and G my own results on the occasion last referred to. The relative situation of the stars known to the early observers appears to be substantially unchanged. For A and D Dembowski finds:

P=300°·7 D=11″·12 (1876·7)

By comparing the measures of Sir John Herschel and Sir James South, with the recent observations of Baron Dembowski, there seems to be an error in Herschel's distance of A F;—

P=28·2	D=36″·52	(1823·6)
28·2	35·98	(1876·7)

The relation of the closer stars can be determined only after a series of carefully repeated measures, but it is at least probable that they will be found to have some physical connection.

No. 441=L 39013

R. A.=20^h 12^m 37^s
Decl.=+28° 46′

This is a 7·5 m. star with very small satellite, measured on one night as follows:

P=65°·4 D=5″·87 (1876·8)

No. 442=Weisse xx. 456

R. A.=20^h 13^m 3^s
Decl.=+37° 11′

A fine group consisting of three large stars, each about 8·5 m. with closer minute companions. The following measures were made on this occasion:

A and B	P=104°·1	D=18″·47
A and a	157·5	4·40
A and b	157·±	7·±
A and c	332·5	19·55
B and d	164·3	8·12
B and C	48·6	17·69

There are several other small stars near not measured.

No. 443=L 39293

R. A.=20^h 19^m 12^s
Decl.=+28° 37′

Angle and distance estimated only:

P=120°± D=10″± Mags. 7·5 . . . 11·5

There is a third star following, about 30″ distant.

No. 445=Cygni 287
R. A.=20h 58m 23s
Decl.=+28° 37′

Very unequal pair; the principal star 7 m. in Lalande.

P=90°± D=4″±.

This is L 40821.

No. 446=Weisse xxi. 344
R. A.=21h 15m 44s
Decl.=+32° 56′

A pair of small stars, the larger 9 m. near and south following a bright star.

P=261°·7 D=2″·30

No. 447=Vulpeculae 129.
R. A.=21h 18m 45s
Decl.=+24° 48′

This is a bright star, about 6 m. with a difficult companion in the direction of 340°. Distance not noted, but probably under 5″. No opportunity was afforded to measure or examine it a second time.

No. 448=L 41874
R. A.=21h 24m 35s
Decl.=+44° 24′

There is some uncertainty about the place of this pair. It is assumed to be the above 7 m. star in Lalande, which is nearly in the observed place, but may be a larger star south following. Estimated as follows:

D=2″± Mags. 7·0 . . . 11·0.

A distant companion preceding.

No. 449=Radcliffe 5335.
R. A.=21h 34m 42s
Decl.=+41° 11′

The three larger stars, A, C and E, were discovered by Sir William Herschel (=H III. 110), and also entered in the Pulkowa catalogue (=*OΣ* 447). The new members of the system, B and D, are very minute, and might be easily overlooked with even a large aperture. My measures of these, and Dembowski's of C and E are as follows:

A and B	P=19°·1	D=6″·78	(1876·8)
A and C	170·5	13·71	(1866·6)
A and D	248·2	17·94	(1876·8)
A and E	45·7	29·13	(1866·6)

Dembowski gives the magnitudes of A, C and E as 7·0, 10·8 and 7·7 respectively. A comparison of the measures of these

stars with the early observations of Herschel, would seem to indicate considerable change, but this is not confirmed by the intermediate measures of Otto Struve.

Herschel	A and C	P=157°·6	D=13″·90	(1783·8)
O. Struve	A and C	169·4	13·86	(1848·3)
Herschel	A and E	49·4	25·97	(1783·8)
O. Struve	A and E	45·3	29·00	(1848·3)

The close agreement between the measures of O. Struve and Dembowski accords with my own results on the occasion of observing the new companions, when the angles came out 170°·5, and 44°·9, respectively.

No. 450=B. A. C. 7931

R. A.=22^h 38^m 40^s
Decl.=+38° 50′

As a double, this beautiful object is found in the catalogues of both Struves, and Herschel (=Σ 2942=$O\Sigma$ 478=H 1802). Struve's magnitudes are 7·0 and 9·2. The colors are very striking, the larger being, according to Struve, reddish gold, and the smaller, ash-color. A third much smaller star was discovered with the 18½ in., and measured once as below:

A and B	P=282°·4	D=2″·66	(1831·6)
A and C	232·0	10·23	(1876·8)

Measures of A and B by Struve. Dembowski gives, P=280°·6; D=2″·80 (1866·6), from which it is safe to infer there is no substantial change in the relation of these stars, and this view is supported by the measures of Otto Struve, Mädler, Dawes, and others. The small star is not a difficult object with the 18½ in., and can perhaps be measured with a smaller aperture.

No. 451=15 Lacertae.

R. A.=22^h 46^m 37^s
Decl.=+42° 40′

This star was seen with a minute attendant, roughly estimated from memory as about 20″ distant. The angle was not noted, and no opportunity occurred to re-examine and measure subsequently.

No. 452=L 44915

R. A.=22^h 51^m 37^s
Decl.=+42° 22′

A fine pair observed about the same time as the preceding, and like that only estimated for the purpose of certain identification:

P=270°± D=6″±

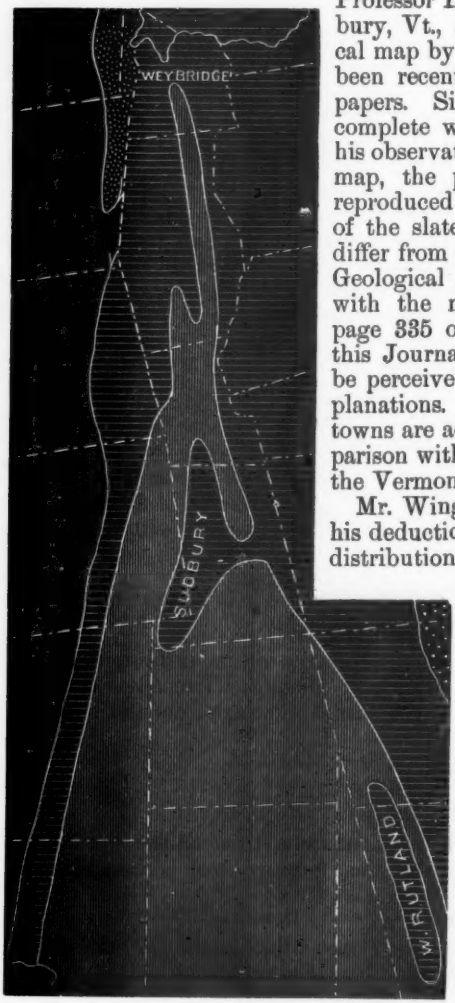
The large star is 6½ or 7 magnitude, and the companion below 12 of Struve's scale.

Chicago, May 5, 1877.

ART. V.—*Supplement to the Account of the Discoveries in Vermont Geology of the Rev. Augustus Wing;* by JAMES D. DANA.

SINCE the publication of the preceding number of this Journal, containing the concluding part of the account of Mr. Wing's discoveries, I have received from Professor H. M. Seely, of Middlebury, Vt., a manuscript geological map by Mr. Wing, which had been recently found among his papers. Since the account is not complete without the results of his observations contained in this map, the portion of it is here reproduced in which his outlines of the slate and limestone areas differ from those of the Vermont Geological Map. By comparing with the map and remarks on page 335 of the last volume of this Journal, the differences will be perceived without special explanations. The outlines of the towns are added to aid the comparison with the colored map in the Vermont Report.

26.



Mr. Wing's map contains also his deductions with regard to the distribution of the formations—part of which are not yet established. The West Rutland and Sudbury areas are both made Chazy along the center and Trenton along the east and west borders, which may be true, although only Chazy fossils have been distinguished in the former, and Trenton in the latter. Along either side of the central slate belt, which is Hudson River (Cin-

cinnati) in age, a belt of color indicating Trenton extends; then others, more remote, for Chazy, Calciferous and Potsdam: and the Chazy east of the slate-belt extends two-thirds of the way to the quartzyte. These points in the map rest mainly on fossils, except the eastern boundary of the Chazy, and the periods assigned to the part of the limestone still farther east.

ART. VI.—*On the relations of the Geology of Vermont to that of Berkshire;* by JAMES D. DANA.

IN my memoir on the Quartzyte, Limestone, and associated rocks of Great Barrington, Berkshire Co., Massachusetts, published in this Journal in 1872 and 1873,* I based the conclusion there presented with regard to the age of the Berkshire rocks largely on the single discovery of Mr. A. Wing, of Chazy fossils in the West Rutland limestone, the only one of his that had then been made public. The wider knowledge of his discoveries which we now have, through his notes and letters, gives a better basis for a decision, and I propose to consider the bearing of the facts as now understood.

We have first to enquire what reasons there are for making the geology of Vermont a key to that of Berkshire. These are afforded both by the geographical and the stratigraphical arrangement of the rocks. The facts given beyond are in part contained in my former memoir. Others are added from my more recent observations.

1. THE GEOGRAPHICAL ARRANGEMENT OF THE ROCKS.

Whatever be true of the whole Green Mountain region, the *western half* of it, including the "Eolian limestone" and its associated rocks, is eminently a natural area, both as regards its topography and its rocks. This north-and-south area is divided among four States—three of Western New England, and the State of New York. But the boundaries of Vermont, the northern of the series, are of political authority, not geological; and so are those of Massachusetts, Connecticut, and New York.

(1.) *The Limestone formation.*—The great limestone belt of Vermont stretches southward, without interruption or diminished width, into Berkshire Co., Massachusetts; through Berkshire, into Western Connecticut; and, continuing its south-by-west trend over Canaan and Salisbury, it passes out of Connecticut, still as wide as in any more northern part, into eastern New York, over the towns of Amenia and Dover, to Pawling. Thence it still stretches southward for seven or eight miles, but

* Vol. iv, 362, 450, (504); v, 47, 84; vi, 257.

with narrowing limits, and finally ends in a narrow strip among the flexures of hard gneiss rocks. It is one of the long Green Mountain formations.

(2.) *The Quartzyte series.*—Associated with the limestone belt, and following mainly its eastern border, there is a *quartzyte* series, consisting in Vermont of quartzyte and crystalline slate or schist (hydromica slate, sometimes chlorite slate), and rising at intervals into mountain ridges. This quartzyte formation commences just abreast of the northern limit of the "Eolian limestone" in Vermont; and it follows it southward through Massachusetts, and into Connecticut, being, throughout, its close attendant.

(3.) *The Slate or Schist series.*—Again, along and west of the central portion of the limestone region, and on much of its western border, there are ranges of hydromica slate often chloritic, with some clay-slate. A broad slate belt is a prominent feature of the region in Vermont west of its center. It commences within ten miles of the northern terminus of the limestone, extends south with increasing width and height, rising at intervals into mountain elevations 2,500 feet or more in height, Herrick Mountains, in Ira, having a height of 2,661 feet, and Equinox Mountain, in Manchester, 3,872 feet (Guyot) above tide-level. It continues with unchanged course into Massachusetts, or rather along the connecting borders of Massachusetts and New York, and this part, south of Vermont, has long borne the name of the Taconic Mountains; and here it rises into peaks nearly as high as those of Vermont, Graylock being 3,600 feet in height, and Mount Everett, 2,634 feet. Further, the Taconic Mountains consist chiefly of hydromica slate more or less chloritic, like the southern portion of the same range in Vermont.

Thus there is a marked unity in the area from north to south indicated not merely in the continuity of the limestone formation, but also in the like continuity of the whole series of associated rocks—limestones, quartzyte and schists—of the eastern, middle and western portions of the great north-and-south area. And this unity favors strongly the idea of oneness in age, in origin, and in mountain-making movements.

The lithological identity is not perfect throughout; yet the differences are introduced by very gradual transitions, evident only as the whole area from north to south is surveyed, and hence they are additional proof of the unity. They are differences mainly in *grade of metamorphism.*

The great central slate-belt of Vermont commences to the north, according to the Vermont Report, in a *clay-slate* belt. Thirty miles or so south, hydromica slate, a more crystalline

rock, commences on the two borders of the clay-slate area, with the band of the eastern border much the broader—corresponding in this with the general fact of a higher degree of metamorphism on the east. Seventy miles farther south, in the Taconic Mountains, and its eastern spur, Graylock, the hydromica slate is in part of somewhat coarser texture and more chloritic, and this same rock constitutes Mount Washington in southwestern Massachusetts, near the southern termination of the Taconic range. It even becomes in part mica slate.

The distance from the north extremity of the slate belt to Mount Washington, through which this small change occurs, is 150 miles.

The ridges in Berkshire south of Graylock, or over the western third of the limestone region, including the ridges either side of West Stockbridge village, and the Tom Ball ridge farther south, west of Williamsville, consist of the same rocks as Graylock, with scarcely appreciable difference. Some of the beds are garnetiferous.

The ridges along a line a little farther east, near the center of the limestone belt, that is, those next east of Tom Ball, and east and west of Great Barrington, have the hydromica slate replaced by mica schist, and then by mica schist and gneiss, part of it a thick-bedded granitoid gneiss. South of Great Barrington, in Sheffield, the schist of ridges in the midst of the limestone area (which has here great width) is a coarse mica schist containing abundantly garnets and crystals of staurolite; and the same staurolitic mica schist exists under similar circumstances near Falls Village, in Canaan, Connecticut, the next town south of Sheffield, and also, farther south and west, in Salisbury. Thirty miles south-by-west of Canaan, about Pawling, and beyond to the termination of the limestone belt, the associated rock is mica schist or gneiss.

The schists, according to the above facts, become more and more crystalline on passing southward—chloritic hydromica slates giving way to mica schist, garnetiferous and staurolitic mica schist, and gneiss; but only by very gradual transitions. It should be here kept in view that the difference in constitution between hydromica slate and mica schist consists simply in the presence of a few per cent (three to six) of water in the mica of the former, and only one or two or none in that of the latter; and that gneiss has merely the distinction of more feldspar and less mica than mica schist.

A parallel change takes place in the associated limestone formation. To the north, in central Vermont, and especially along the western portion of the limestone region, occur the areas of grayish half-altered or semi-metamorphic limestone, affording distinguishable fossils. Further, the limestone of this northern

portion of the Eolian limestone is generally very fine in grain even where of the purest white color. In Pittsford and Brandon are found the best of statuary marbles, looking like the finest loaf-sugar in texture. South of Pittsford, in Rutland, the marble is a little less fine in its grain than it is farther north; in Berkshire, it is mostly much coarser, none answering to statuary marble existing anywhere; and in southern Berkshire and Canaan, Ct., it is still coarser in crystallization, and abounds also in many places in tremolite, white pyroxene, and mica. Thus the fact of intenser metamorphism to the southward is as plainly apparent in the limestones as in the schists.

After this survey of the facts we have to admit that the differences are so distributed geographically as to prove unity of area and rocks, rather than diversity.

Similar differences, depending on degree of crystallization, are found in going *from west to east* in Massachusetts, as in Vermont. The rock of the Taconic Mountains is mainly hydromica slate and chloritic hydromica slate; and of ridges, *farther west*, in Columbia County, New York,—as in Copake at the foot of the mountains,—a finer hydromica slate and clay-slate, with bluish semi-crystalline limestone. But going eastward, in Berkshire, to Stockbridge and Great Barrington, and farther east to Monterey and Tyringham, there are, as illustrated in the facts stated beyond, first a coarser hydromica slate, partly garnetiferous; then fine-grained mica schist and gneiss; and then coarser and harder varieties of the latter rocks; and the crystalline limestone, which is almost free from foreign crystallizations in Stockbridge and West Stockbridge, contains large crystallizations of white pyroxene or tremolite in some places in Lee, Monterey and Tyringham.

2. The Stratigraphical Relations.

In Vermont we have found the following cases of *conformable superposition or interstratification*, as described in the account of Mr. Wing's researches, and illustrated in the figures of sections accompanying.

(1.) The limestone and schists conformable.

(2.) The quartzyte and schists conformable.

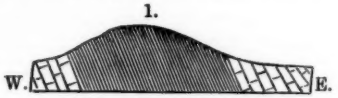
(3.) The quartzyte and limestone, and also the quartzyte, schists and limestone, conformable.

The *first* of these Vermont cases of conformability is illustrated in the sections on pages 338, 340, 344, 346, 347 of the last volume of this Journal; the *second*, in the constitution of the quartzyte formation, as explained on page 411; the *third*, in the sections presented on pages 340 and 412.

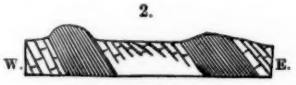
The following facts show that wholly similar cases of conformable superposition exist in Berkshire.

(1) *Interstratified limestone and schists.**

Fig. 1 represents a very common case of this first kind. Chloritic hydromica slate, dipping eastward, lies between strata of limestone which have the same dip. Examples occur in the southern third of the ridge called Tom Ball, southwest of Van Deusenville; also in Alvord, west of Tom Ball; in West Stockbridge; along much of the Taconic range, the slates



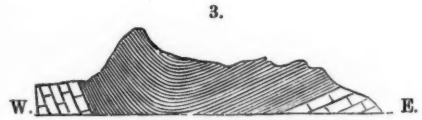
South end of Tom Ball.



West of Glendale.

having eastward dip between limestone strata of like dip; and in many other places. Two miles east of Tom Ball, in Glendale, the structure is repeated with thin strata of the schist as in fig. 2; moreover, the schist, is here a coarse *mica schist* instead of hydromica slate. West of the village of Great Barrington, there is a ridge of schist between limestone, as in fig. 1, but the schist is mica schist with some gneiss, and a thin bed of quartzyte. A few miles farther south, in Sheffield, in the midst of the limestone area, and not far from its center, the conditions in fig. 1 exist, but with the schist a mica schist containing staurolites and garnets.

Examples also occur in which the dip is comparatively small. At the north end of Tom Ball the position of the rocks is as represented in fig. 3, in which on the east the limestone



North end of Tom Ball.

West of Glendale.

dips west 18° to 20° under the chloritic hydromica slate, containing in some places many garnets, and passing also into mica slate. The schist overlies the limestone in a synclinal.

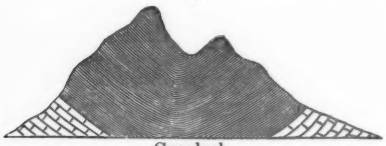
East of the north end of Tom Ball, on the road to Glendale, the limestone dips eastward 25° under a bluff of garnetiferous mica schist (fig. 4).

The facts connected with Graylock, in Northwestern Massachusetts, the highest of the Taconic peaks, point to a synclinal (or a synclinal with subordinate anticlinals and synclinals),

* In all the figures the blocked areas represent limestone; the simply lined, slate or schist; the lined and dotted, quartzyte. Moreover, the right end is the *eastward* end.

much like that of the north end of Tom Ball, as shown in figure 5, by Emmons, here repeated.* The same structure exists in Mount Washington in Southwestern Massachusetts, the next highest summit of the range. At the *eastern* foot of this mountain the limestone dips *westward* at a small angle, (25° to 30°), beneath the chloritic hydromica slate, as I have described in a former article ;† and the more eastern and highest peak of the mountain, called Mt. Everett, partakes of

5.



Graylock.

6.

Half mile N. of Housatonic, west of the Old Furnace.

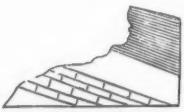
this westward dip; while in Copake, at the *western* foot, where the dip of the slate is eastward, the limestone dips *eastward* conformably to the slate, (the strike N. 20°–25° E., dip 40°–50°). In my examinations in Copake I had the guidance of Mr. William Miles, who had thoroughly explored the limestone localities. Besides the many conformable outcrops over the interior of the valley, there were others of large extent close to the slate of the mountains, and one where the limestone and slate were seen in contact.

Again, half a mile north of Housatonic, west of the river, the section in fig. 6 is seen in an abandoned quarry. The limestone dips 10° to 25°, and passes beneath mica slate. In

7.

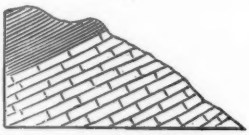
Canaan Mountain. Southwest Front.

8.



Falls Village, Canaan. West side of river.

9.



Hill west of the village of Tyringham.

Canaan Mountain, Connecticut, in the southwest front there are 150 feet of limestone at base, dipping 15° to 20° to the eastward underneath mica schist (fig. 7). In the same town, at Falls Village, west of the Housatonic River, a ridge (fig. 8) consists of limestone below dipping at an angle of 15°–20° under a mica schist containing garnets and staurolites. The mica schist forms the upper part of the hill and the limestone outcrops toward its base.

* See last volume of this Journal, p. 347. † This Journal, III, vi, 266, 1873.

Further, in the most eastern of the limestone areas, in Tyringham, twelve miles east of the Taconic range, a hill, just west of the village, having a height of 450 feet above the bridge near its base, consists of well stratified limestone to within sixty-five feet of the top, (fig. 9); and above this of mica schist (the contact distinct), and very hard whitish thick-bedded gneiss; the whole dipping southeast 20° to 28°, with the strike N. 40°–45° W. Within the limestone stratum, fifty feet below its upper limit, there is a thin layer of mica schist.

These examples are sufficient to illustrate the point in view. Two others are given beyond.

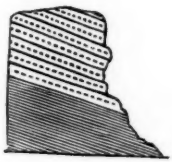
(2.) *Interstratified quartzyte and schists.*

At the east front of Monument Mountain, half way from Stockbridge to Great Barrington, quartzyte overlies mica schist and gneiss (fig. 10), the dip 15° to 25°, to the southeast. The

11.

West end of Monument Mountain.

10.



East front of Monument Mountain.

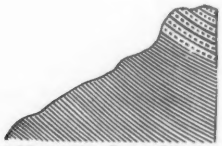
quartzyte is a hard kind without bedding, but vertically jointed. At the western end of the same mountain, opposite the village of Housatonic, the quartzyte, which forms the bold part of the front and rises to its greatest height a little back from the front, is at last capped by mica schist and gneiss (fig. 11), a continuation of the stratum that *underlies* the quartzyte of the eastern front. The quartzyte is here mostly devoid of bedding; but in its upper part, the bedding is distinct and parallel with that of the schist. This stratum of schist is locally a handsome granitoid gneiss half a mile to the eastward, at the top of the western half of Monument Mountain, showing in hand specimens no bedding whatever; but in most parts of the mountain it is rather mica schist than gneiss.*

East Mountain, rising from the Great Barrington Valley half

* This section of the western end of Monument Mountain is not here continued to its base, because the observations of this part were not wholly satisfactory owing to the concealment of the rocks by the soil. The stratum of schist in my former published section was inferred to exist there below the quartzyte, as I state in describing the section, from the great number of blocks over the surface; and that of the underlying limestone from small exposures along a path up the lower slopes of the mountains south of the old furnace, and from some very large masses of limestone on the east bank of the river, above the furnace, which may possibly be transported blocks.

a mile east of the village, consists below of thick-bedded gneiss, similar to part of that of Monument Mountain, but contorted in its bedding and dipping 40° to 50° to the eastward; at top, for the upper 100 feet, it is laminated quartzyte (fig. 12), resembling the laminated quartzyte of many other localities in the limestone region. This quartzyte is gneissoid in many places, or a sandy gneiss, making manifest thereby the close relations of the two rocks.

12.



East Mountain, Great Barrington.

13.

Cobble Hill, South Canaan.

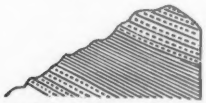
In South Canaan, east of the village, Cobble Hill consists below, to the west, of a soft-bedded quartzyte, dipping southeastward 40° (fig. 13), twenty to twenty-five feet of which are exposed on the road side; next above, a stratum of mica schist and thin-bedded gneiss, containing scales of both black and white mica; and then a whitish, granite-like gneiss. The quartzyte contains at intervals, in its upper part, streaks of black and white mica, and thus exhibits its relations to and passage into the overlying gneiss.

East of the village of Lee, a low ridge consists below of quartzyte; at middle of mica schist; and at top of quartzyte—all dipping eastward 15° to 25° (fig. 14).

(3.) *Interstratifiel quartzyte, limestone, and schists.*

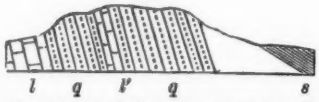
The fact that the quartzyte keeps by the side of the limestone, with small exceptions, from its northern limit southward to Connecticut suggests that there is a close stratigraphical connection between them. Further, seeing that the limestone occurs interstratified with the schists, and also the quartzyte of the same region with the same schists, there would seem to be hardly any ground for questioning the inference that the quartzyte and limestone are parts of the same great series of forma-

14.



East of the village of Lee.

15.



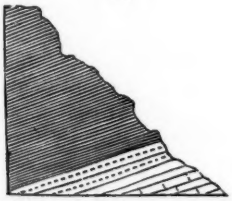
Quartzyte ridge east of south end of Tom Ball.

tions. On these grounds and the occurrence of limestone near by, it would be a reasonable inference that the strata of

fig. 14 and the limestone are conformable. But there is also demonstrative evidence of this relation in sections. Fig. 15 represents a section of a ridge east of the southern part of Tom Ball. Limestone, dipping eastward 70° to 80°, adjoins a hard quartzyte; and in the quartzyte there is a stratum of impure limestone (*l'*) dipping with the other limestone.* This stratum indicates the dip of the quartzyte, which is elsewhere without bedding, and shows the conformability of the two rocks. East of the ridge there is an outcrop of mica schist, thirty rods east of the eastern outcrop of quartzyte, having nearly the same strike though less dip; so that we have all three rocks associated in the same section.

Fig. 17 represents several alternations of quartzyte, schist, and limestone, near Devany's quarry, four miles east of Great Barrington, all with small eastward dip; and here also mica schist and gneiss alternate with the other rocks, and, besides, constitute the upper stratum at the quarry. At this place, the intervals of earthy surface between the outcrops are as follows: between 3 and 4, fifty yards; between 4 and 5 (limestone and overlying quartzyte), hardly a yard; between 5 and 6, a marshy spot of forty yards; between 6 and 7, fifty yards; 7 and 8 (limestone and overlying gneiss) are in contact, and so also are 9 and 10 (quartzyte and overlying gneiss). No. 1 is the eastern border of the limestone of the Konkaput valley. The

16.



Three-mile Ridge, west side of Konkaput Valley.

17.

Devany's Quarry, east side of Konkaput Valley.

thinner lower layers of quartzyte in this section have little lateral extent. Devany's bluff is part of the southwestern foot of Beartown Mountain. The schist at the top of the bluff, (10, fig. 17), continues upward to a height of 800 or 900 feet above the upper quartzyte, being the rock of the mountain; and at this southern extremity of the mountain it has a small dip (10° to 25°) to the northeastward, so that the quartzyte and limestone of the Devany region is overlaid by at least 800 feet of schist. This schist is mostly a whitish and gray gneiss, very tough and hard; but with it there is granulyte, gray and black mica schist, and blackish hornblendic schist.

* This Journal, III, v, 84.

Fig. 16 exhibits the stratification in Three-mile Ridge,—a ridge on the opposite side of Konkaput valley from Devany's bluff, and shows the same succession essentially as on the Devany side—namely, limestone (that of the Konkaput valley) below; next quartzyte; next a great thickness of gneiss—not less than 800 feet. Three-mile Ridge extends southward (S.S.E.), with rather an abrupt front, and shows in a distant view nearly horizontal lines of stratification. The dip is mostly 25° to the northwest; but at base, toward the notch passed through by the road to Great Barrington, it is diminished to 8°. The gneiss (as may be seen three or four hundred yards south of the notch) rests on a stratum of quartzyte. It is hard quartzyte, but has the bedding distinct. It includes, besides some interrupted micaceous lines, a layer a foot thick of gneiss; but this gneiss layer, after a few rods, fades out to the northward and becomes a layer of quartzyte scarcely distinguishable from the rest of the quartzyte. Thus again, the distinction between quartzyte and gneiss in Berkshire proves to be of no more importance than that of quartzyte and hydromica slate in the quartzyte formation of Vermont. The soil conceals at this place the lower part of the quartzyte stratum, and the underlying rock or rocks; but, half a mile southeastward, along a road which runs nearly parallel with the mountain and not far from its base, and also between this road and the mountain, the limestone of the Konkaput valley outcrops with a small northwestward dip (15°–20°), conformable to the schist of the mountain; and these outcrops continue numerous for more than a mile. In one knoll, toward the mountain, the beds were found to dip eastward, but this was an exceptional case. Elsewhere the dip was northwestward, and at one spot the limestone was seen directly overlaid conformably by the schist.

I have above given the facts of my own observation. The same general conclusion with regard to the interstratification of these formations was long ago reached by Professor Edward Hitchcock, and announced in his Report on the Geology of Massachusetts. Speaking of the quartzyte, he says (Report of 1841, p. 590): "it alternates with and passes imperceptibly into gneiss and mica slate; and in fact it might very properly be regarded as a member of the gneiss and mica slate formations;" in Berkshire "it is frequently interstratified with gneiss and mica slate, especially along the eastern side of the valleys, as in Tyringham, Great Barrington and Sheffield."

He also states (p. 573 and beyond) that in Berkshire, the limestone occurs interstratified with the gneiss, mica slate, talcose slate and quartz rock of the region; that in New Malborough and Tyringham it is found in beds between the strata of gneiss, as at Hadsell's lime quarry; and that its interstratification with mica

slate may be seen in numerous places in all parts of the county. He adds that he had not "met with a spot where the limestone is in direct contact with quartz rock; but as this rock frequently alternates with gneiss and mica slate, and the latter with the limestone, they must all be regarded as interstratified with one another."

Before Professor Hitchcock's observations were made, Professor Dewey announced in this Journal, in 1819, that the Berkshire limestone at the *Cave* or *Falls* in Adams, east of Williamstown, and also west of the Hoosac, *rests on mica slate.* Further, Professor Silliman, in the second volume, 1821, gives an account of the interstratification of the limestone and mica slate in Salisbury, Ct., west of the Housatonic, saying that "in the course of five or six miles there are as many alternations and successions of these two rocks," and "their junction in some places is exactly defined."

Abrupt transitions in dip or strike occur in some places which suggest that there is unconformability. But the above-explained actual sections prove them to be exceptional; and this is sustained by other facts. They are common over the broad areas of crystalline limestone moderate in dip, and of rare occurrence over the regions of schist, and also in the limestone areas close adjoining the schist. When making my first section of Western Connecticut, I passed from the schists, which had given regular dips and strikes, to the wide limestone area of Canaan; and expected to find in it essentially the system and regularity of position met with in the other rocks. But the observations of dip and strike were soon found to be of little value except as regards questions of local interest; they could not be used to determine either the direction of the uplifting force, or that of conformability in the formations, because of the abrupt local changes, which sometimes amounted to 50 or 60 degrees in dip and strike in a few rods. The same irregularities occur over all the other limestone areas of the Green Mountain region except where the beds dip at a high angle. Examples occur in the broad valley east of Monument Mountain, at a quarry half a mile distant from the bold front of the mountain, where the beds are vertical; in the valley west of Devany's quarry, just west of the place where the section represented in fig. 14 was obtained; in the Housatonic Valley between Housatonic village and the old furnace; in the vicinity of Glendale and Stockbridge; in the valley of West Stockbridge, and in other places. In sections observed close by the intervening ridges of schist, the irregularities are with a rare exception absent and the conformability to the schist is placed beyond doubt.

An unconformable limestone ledge is alluded to above as existing in the valley near the Devany bluff. The *conformable* limestone-outcrops extend along the side of the valley for a

fourth of a mile. But toward the west end of the series, in front of the conformable outcrops, that is, a little nearer the middle of the valley, there is a ledge with a dip of 80° to 85°, instead of 25° or 30°. Its little extent shows that it is one of the local exceptions. And this is made more manifest, and its existence partly explained, by the fact that in the same transverse line across the flat valley, and just beyond its middle, there is a hill of schist whose beds dip 50° to the westward, instead of the usual 25° or less. The schist in the mountains forming the sides of the valley has little variation in dip for several miles.

The reason for these irregularities is to be found in the inflexibility of uncrystalline limestone as compared with other uncrystalline rocks (shales and sandstones) and its tendency, therefore, to break and become irregularly shoved up under uplifting or flexing action. Moreover, the limestone areas appear generally to be regions of anticlinals, and the schist areas those of synclinals; and the former, whatever the rock, are usually the places of greatest surface fractures, and the latter, of least. In the synclinal, the limestone beds are kept in place beneath the overlying strata; and therefore, the irregularities in the limestone should not appear close to the schist.

In such a region of extensive upturning and mountain-making as that of the Green Mountains there must be many lines of great fractures and faults. Yet the only case of non-conformity in dip adjoining a ridge of schist which I have observed occurs near the middle of the limestone region within half a mile east of Great Barrington village at the foot of the section represented in fig. 12. The limestone dips 80° to 85° to the westward; and the schist, at its nearest outcrop—10 yards—dips 50° to 60° to the eastward, the strike being N. 10° E. The schist is mostly a thick-bedded gneiss; and its antique look and massiveness, with its contorted texture, led me, in view of the non-conformity of dip, to suspect actual unconformability, and also difference in age and system of uplift. But this idea was soon set aside by the discovery that the top of the ridge was made partly of quartzyte, like that of Monument Mountain three miles north, and by other facts showing that both the schist and quartzyte were part of the limestone series.

The facts here brought forward fully establish the conclusion that the limestone, quartzyte, and schists under consideration have the same stratigraphical relations in Berkshire that they have in Vermont. They therefore sustain the view that these formations constitute together a conformable series; and, also, that the area they cover is geologically one.

[To be continued.]

ART. VII.—*On certain new and powerful means of rendering visible the Latent Photographic Image;* by M. CAREY LEA.

THE development of the latent or invisible photographic image produced by the action of light is beyond all question the most remarkable and the most interesting fact with which photo-chemistry has made us acquainted. Our knowledge, however, of the substances capable of exhibiting this power, has increased with singular slowness. It commenced with the discovery, by the late Rev. Mr. J. B. Reade, in the year 1836, of the existence of this power in *gallic acid*, and not long after *pyrogallol* was found to possess the same property in a more energetic degree. Mr. Robert Hunt discovered that *ferrous sulphate* acted somewhat more powerfully than pyrogallol, provided that a soluble salt of silver was present. This was more than twenty years ago. Since then, no useful addition has been made to this list of so-called "developers," though several of simply scientific interest. I was enabled to add to it *hæmatoxyline* about ten years since. *Morphia* has been found to have limited developing powers. When pyrogallol or gallic acid was employed in the absence of a soluble salt of silver, it was found that the activity of these bodies could be greatly increased by the presence of an alkali (alkaline development), for which purpose ammonium carbonate has been generally employed. It has been recently affirmed that in the ammonia-pyrogallol process, pyrogallol could be replaced (though with less energetic action, and therefore not advantageously) by a decoction of coffee berries, probably by reason of the quinic and caffetannic acids contained; and possibly by one or two other substances. This I believe represents the information acquired up to the present time.

In the following investigation I propose to show:

1. That the number of bodies endowed with the power of developing the latent image, so far from being very limited, as hitherto supposed, is, on the contrary, very large.

2. That contrary to what has been generally held, *potash* acts more powerfully in aiding development than ammonia; that there exist substances which develop with more or less energy in the presence of potash (e. g., mannite), but which have no such power in the presence of ammonia,* or alone.

3. It has been generally thought that the most energetic form of development, when no soluble salt of silver is present, is that which depends on the use of free alkali. I propose to show that there exists a form of development which under

* Unless possibly after greatly prolonged exposure.

appropriate conditions is more powerful than any yet known, in which there is *no free alkali present.*

4. It has been held that ferrous salts act only in the presence of a soluble salt of silver, and scarcely attack the silver haloid in the film, to produce an image in the absence of silver nitrate or other soluble silver salt. This also I think can be disproved.

As the development of the latent image depends (in the class of cases which I shall here consider,) upon a reduction of the portions of the sensitive substance which have been acted upon by light, it is evident that it is amongst reducing agents that we must look for bodies possessing this power. But here we are at once met by the fact that it is not the reducing power alone that is involved. We find that many substances which reduce silver salts energetically, have no power to evoke the latent image, and also that the developing power, where it exists, stands in no sort of relation to the energy of the reducing power. It is an *elective* power that is required, a tendency to reduce, not the whole surface, but only those parts that have been acted upon by light, and to spare the others. For example, it is easy to prepare alkaline solutions of ferrous salts, by having present a sufficient quantity of neutral potassium tartrate. But such solutions, applied to a sensitive surface that has received sufficient exposure under a negative, or in the camera, for ordinary development, seem to attack equally those parts that have been acted upon by light and those that have not. So that the sensitive surface darkens uniformly without showing the vestige of an image. Other similar cases will appear farther on.

In the following series of investigations a pure photographic paper was selected as the material for containing the sensitive substances. In the selection of the sensitive material itself, the object was to obtain the most highly sensitive possible. Silver iodide and bromide together are more sensitive to light than either separately, but also are more subject to irregular reduction. The best means of removing this difficulty without impairing the sensitiveness, I found to be the addition of silver chloride, which previous investigations had shown me to possess this power in a very remarkable way. Accordingly the present investigation was conducted upon surfaces containing these three substances together. The proportions used were those resulting from a solution containing eight grains potassium bromide, two of potassium iodide, and one and a third ammonium chloride, to the ounce. This proportion was that which gave the best results and was maintained in the experiments throughout. Facility of development is always increased by the presence in the sensitive film of some suitable organic substance. In these investigations a decoction of *cocculus indicus* was employed: this was applied together with the haloids,

first; after drying, the silver solution. Finally the sheets were very thoroughly washed out, to remove every trace of excess of silver nitrate and of all other soluble matter. To this careful washing much importance attaches. If any cocculus were left in the paper, it might, by dissolving out in the developing solution, confuse the result, inasmuch as cocculus with potash exhibits some developing powers. Every trace of it was therefore removed by the most careful washing, and as an additional precaution, the most important results were repeated on paper prepared with haloids only, in order to control the conclusions with exactness.

RESULTS.—A. *Sugars.*

Several sugars when heated with dilute aqueous solution of potash exhibit power of development. *Glucose* and *cane sugar* very slightly. *Milk sugar* produces a light metallic looking image on a dark ground. *Glycocine* was without effect. *Manna* acts very powerfully, producing an image perhaps as bold and strong as any substance hitherto known. The contrast between this strong action of mannite and the very weak action or entire inactivity of the other sugars named seemed very singular. It was thought that it might possibly arise from the fact of mannite not being a carbohydrate like the others mentioned but containing more hydrogen than sufficient to convert the oxygen into water. Therefore another sugar of the same class, *quercite*, was tried, but was found to possess no developing power whatever. The remarkably energetic action of mannite remains therefore without explanation. This substance and milk sugar, offer a good illustration of what has just been said of developing power being not necessarily proportional to reducing power. Milk sugar in conjunction with potash energetically reduces the silver haloids, but shows little developing power, while the converse is the case with mannite.

The image produced by mannite is of a redder shade than that resulting from any other developing agent.

B. *Glucosides.*

Daphnin gave a moderately strong image; its derivative, *Daphnetin*, a bolder and fuller. *Phloridzin* and *glycyrrhizin* gave no images. So-called *flavin* gave no image when simply heated with potash, but when boiled with potash and zinc turnings gave a moderately strong one, doubtless by the conversion of quercetin into *quercitrin*. Accordingly an infusion of *white oak bark* was found to give a good image. *Solanin* gave a moderately strong image, as also did *thujine*. *Colocynthine* (decoction of colocynth was used) gave little or no result. *Æsculin*, a fair image. In all cases the substance was heated with dilute aqueous potash before use.

C. *Acids.*

Of a number of organic acids tried with excess of potash, one only, *cevadic acid*, exhibited tolerable developing power. *Phenol*, and *glyceric*, and *gentianic* acids powerfully reduced the silver haloids, but with little or none of the elective power necessary to produce an image. One, *oleic*, produced an image lighter than the ground. *Santonic*, *sinapic*, *gummic*, *malic*, and *hippuric* acids produced either faint traces of an image or none at all. *Vanadous acid* (potassium vanadite with excess of potash) failed to exhibit any developing power.

D. *Resins.*

Resinous substances for the most part dissolve easily in dilute aqueous potash, and exhibit more or less developing power. Foremost among them is *guaiacum* which gives a very vigorous image, not far short of what may be obtained with pyrogallol. *Balsam of tolu* and ordinary *resin* both have moderate developing power. Resin scarcely attacks the parts that have not been acted upon by light, whereas tolu does so. Resin of *podophyllin* gives a strong image.

E. *Essential Oils.*

When *oil of cloves* is boiled for a few moments with dilute aqueous potash, and the mixture is then much diluted with water, it acts slowly on the image, but as the action is sustained and clear, there results at the end of about an hour, a vigorous and very clear image. *Oil of Roman chamomile* acts somewhat similarly, but more feebly. *Oil of peppermint* produces an image of a gold color, and at the same time darkens the parts not acted upon by light, thus producing an image on a darker ground. Something similar has been already mentioned in the case of oleic acid. In these cases, where the light acts, the developing agent seems to reduce metallic silver, elsewhere, a dark basic salt, perhaps with organic matter in combination, is formed.

F. *Bases.*

Daturin (atropin?) gives a weak image. *Codein*, none. As a general thing the organic bases exhibit little tendency to evoke the latent image.

G. *Pyrogallol.*

In the course of this investigation, some interesting and new observations were made in connection with this well known agent, that deserve mention here.

Pyrogallol is well known to have, when employed by itself, considerable developing power, which however, is greatly increased by the presence of caustic or carbonated alkalies. It appears that these alkalies can be replaced with sodium *metaphosphate*, with about equal results. With sodium *hypophosphite*,

the effect is fair but inferior. But with potassium *formate*, a more energetic result is obtained than by any other method of using pyrogallol: a stronger development than by any of the methods now in use.

H. *Various.*

Trials were made with a considerable number of substances of vegetable origin whose constitution or properties seemed to indicate that they might exhibit power of development. In all cases they were boiled a few moments with dilute aqueous potash, as it was found that in that way their characteristic actions were most fully brought out. *Aloes*, *uva ursi leaves*, *areca nuts*, the bark of the *berberin tree*, *morus tinctoria*, exhibited very considerable developing power. *Gratiola*, *ipecacuanha*, *pimento nuts*, well marked power, but less than the foregoing. A decoction of *Iceland moss* exhibited the properties already described in the case of oleic acid and essential oil of peppermint. Many other substances were examined, and showed either faint traces only or absence of power, e. g., *litmus*, *carthanus*, *rutin*, *bryony*, *stavesacre*, *colchicum*, *turmeric*, *nux vomica*, *caffein*, *berberin*, etc.

Acetone, in conjunction with aqueous potash, is a powerful developer and gives a bold and vigorous image.

Aldehyde, with potash, gives no image, a result that seems somewhat remarkable.

I. *Cuprous oxide dissolved in Ammonia.*

A colorless solution of cuprous oxide in ammonia develops a strong image, and is interesting as being one of the very few entirely inorganic developers discoverable. As might be expected, its action is heightened by the presence of many organic matters.

When to a solution of cuprous oxide in ammonia, *formic acid* is added in quantity not quite sufficient to neutralize the bases, and this solution is applied to the latent image, a powerful development is obtained, resulting in a pure black image. *Lactic acid* exhibits a similar reaction, but less perfectly, and no doubt a large number of other organic acids share the same properties.

Various substances that develop in presence of potash, especially *gum guaiacum*, *gallotannic acid* and *manna*, heighten the action of the cupro-ammonia solution. Others do not, of which *picrotoxin* (*cocculus indicus*) is an example. Of all the substances named, guaiacum appeared to have the most power, and next to it, perhaps formic acid.

J. *Ferrous Salts.*

The salts of ferrous oxide have proved to be the most interesting and remarkable of all the bodies examined, in their

action on the image. When a salt of silver is present in solution, to suffer reduction and to furnish silver for building up the image to be developed, as in the case of the so-called "wet process," ferrous sulphate is the most powerful developing agent known, and is accordingly, always employed. But in the absence of silver in actual solution it is powerless. It is in connection with such sensitive surfaces (i. e., those from which silver nitrate or other soluble silver salt has been removed by washing), that the present investigation is made, and I have verified this fact, already established, very carefully. A surface of sensitive paper, from which all silver compounds have been removed, may, after receiving a latent image, be left long in contact with ferrous sulphate without an image being developed.

Desirous of finding a means of applying ferrous salts to these developments, my first efforts were directed to the formation of alkaline solutions containing ferrous oxide in solution, but they did not appear to possess any power of development. I then tried ferrous oxide in combination with organic acids, and here at once most interesting results followed. Several organic salts furnished beautiful developments, among which may be especially mentioned *ferrous succinate*, *lactate* and *salicylate*. The succinate is best used by forming a slightly acid solution of ammonium succinate, and adding to it a solution of ferrous sulphate in quantity not quite sufficient to form a precipitate. Many other ferrous salts, among which may be mentioned *citrate*, *formate* and *tartrate*, give images, but much inferior to those already mentioned. The succinate and lactate develop so well that they might pass into use, were they not, as well as all other developing agents, so much exceeded by the oxalate.

Ferrous oxalate, when applied to paper sensitized in the manner already described, exhibits developing powers of a very remarkable kind. A piece of sensitized paper exposed for a very brief period to diffuse light under a negative, and then cut into two pieces and tried, the one with this development, the other with the ordinary alkaline pyrogallic development, exhibits the following differences:

The same exposure which with the alkaline pyrogallol gives a weak and sunk-in image after a protracted development, gives with ferrous oxalate a bright, bold image, and this in a much less time. The development is particularly clear and clean. The unexposed parts are not attacked: the developer possesses a great deal of that elective power previously spoken of, which causes it to react strongly on those parts which have received the influence of light, and spare those which have not.

Ferrous oxalate is easily obtained by adding a strong warm solution of oxalic acid to one of ferrous sulphate. A bright

yellow precipitate falls, which continues to increase for some time, and which may easily be washed by decantation. The method of employing it is by dissolving it in an aqueous solution of neutral potassic oxalate. The latter substance is to be dissolved in about three times its weight of hot water, and the precipitated and washed ferrous oxalate is dissolved in it to saturation. A deep red solution is obtained, which for use needs only to be diluted with from five or six up to twenty or thirty times its bulk of water, according to the energy of effect desired.

An active solution of ferrous oxalate may be obtained by simply adding a solution of ferrous sulphate to one of neutral potassic oxalate, in quantity just sufficient to avoid forming a permanent precipitate. But the first described method gives the best results.

Philadelphia, May 8, 1877.

ART. VIII.—*On the possibility of Transit Observation without Personal Error;* by S. P. LANGLEY.

THE different modes of dealing with personal equation may be divided into two broad classes: (1) those which attempt to diminish or eliminate it during the act of observation, (2) those which aim to find its amount, and to apply a subsequent correction. Redier, Braun, A. S. Herschel, Wheatstone and many others, have proposed devices falling in the first category; all of which involve the use of a movable reticule, which, theoretically, should travel at the same apparent rate as the star. The mechanical difficulties of doing this accurately (considering that every star has a different apparent rate) are extreme, and they almost necessarily involve the use of delicate apparatus forming a part of the telescope. These difficulties have never been overcome,—scarcely attacked, and were they vanquished, others would remain. This method then, though perhaps still susceptible of success with skillful treatment, has not yet proved of any practical utility. A very different proposition, originally due I think to M. Faye, and made as long since as 1858, is that for the use of photography in transits. This evidently, if practicable, does away with personal error, and if the exposure be reduced to a very brief time—let us say to $0^s{\cdot}01$—it is clear that the motion of the star is immaterial, for we have its position photographed relatively to the wires, as it was at a given instant. This method has been little used, except for the sun, owing to defective light, but though not yet practicable save in limited cases, it is perhaps not too much to say that it will probably be the method of the future.

Under the second class come the ordinary procedures for the determination of relative error, or the personal equation between two observers; such as their interchange of stations, or their observing the same stars with adjacent instruments, or with the same instrument jointly, etc. These comparisons are liable to error themselves, are commonly tedious, and often compel long journeys. When successful, they give, not the absolute error, but the error as compared with another error, itself subject to an unknown variation. Unsatisfactory as all this is, however, such methods are in common use, and will remain common till better are provided. An effort in this direction has stimulated the invention of a great number of devices to enable the observer to determine his equation by comparison with the transit of an artificial star, itself, self-recording. This suggestion (said to have been first made by Prazmowski in 1854), has been the parent of many attempts, among which those of M.M. Hirsch and Plantamour, and that of M. Wolf of the Paris Observatory, particularly deserve attention; and of subsequent ones too numerous for description, though the apparatus of Professor Eastman, U. S. N., and of Professor Rogers of Harvard College Observatory, may be cited as favorable examples. It may be observed that the use of such apparatus, however ingenious, can only determine the personal error then and there, and can give no guarantee against its variability, which is, after all, the most formidable difficulty. Were this a history of devices for correcting or eliminating personal equation, a volume might be easily filled with an account of proposals coming under one or the other of these two heads, for the literature of the subject is fuller than most are aware.

To propose to offer anything new at this day on such a subject may seem to be hardy. I venture however to ask attention to a method for eliminating the equation on the star itself, which has worked well on trial.

Before stating it, let us observe that we restrict the words "personal equation" here, to the correction for the error committed by the observer in noting the time of transit of a star owing to the motion of the latter, and that for brevity we leave untouched the effect of certain minute irregularities familiar to the observer, such as the actual inequality of wire intervals which should be equal, or the apparent irregularity in the motion of the star due to atmospheric tremor. A particular interest in the subject has long led me with others, to try to remove the error from the observation, in the act of observation itself. One mode which presented itself many years since, and which has been tried in numerous subsequent plans I have made, was to view the star only for a brief time through a narrow linear aperture in a moving screen, thus exhibiting its

position in the field for a moment only, though the use of a flash of light which for an instant illuminates the wires has seemed better. In any case the essential idea was to treat the eye as it has been proposed to use the photographic plate, and to impress upon it by instantaneous vision an image of the position of the star independent of personal error (in one sense,) since the star was to have sensibly no time to move, while the view lasted, while yet the effect then seen would remain (owing to persistence of vision,) quite long enough for cognizance. After a great number of forms of the movable screen were considered, they were set aside for the flash of light from the electric spark.

To make the present plan plain, let us recur to the use of photography as an illustration, and first suppose that the transit wires are twenty-five in number and so near that a star occupies one second in passing from one to another. In the place of a transit lamp, let a wire, attached to a repeater in the clock circuit, dip in a mercury cup, and the circuit being broken every second by the clock, recording simultaneously on the chronograph; the otherwise dark field will be illuminated by a brilliant instantaneous flash, by whose light the wires are projected with the crossing star on the sensitive plate of the camera. If this plate be renewed or moved downward at each flash, we obtain twenty-four successive pictures while the star is crossing, each showing it at the extremity of its luminous traces in precisely the same relation to the adjacent wires, since the wire interval in time, and the flash interval, are identical. If then the star is caught by the first flash, one-third of the way from the first to the second wire, it will be exhibited by the next flash one-third the way from the second to the third, and so on. Any one of these photographic pictures would on being measured, and compared with the chronographic record give the time of transit free of personal error, but this method, applicable if at all, at present, only to the brighter stars, is here used only in illustration. Even were it practicable we do not always have a photographer or photographic material at command, but we have the eye at all times, and I hope to show how we may obtain from it, results of the same order of accuracy as those we could expect from the photograph, and equally exempt from personal error, in the sense in which we have defined it.

First as to the difficulties to overcome. In the case of the photograph, there is an opportunity for subsequently measuring the distance of the star from the wire, which we have not with the eye. There is one particular case however, where the result is the same for both, that, namely, when the flash comes, the star is on the wire and bisected by it; in this case we know its position as accurately by the eye, as if we bisected its image on the plate by the wire of our measuring micrometer, with

the same magnifying power. If we suppose, then, that the star observed was in the equator, and that, by a happy accident, the first flash came just as it was crossing the first wire, this wire would be sharply defined on the disc of the star and bisecting it, and the simultaneous record on the chronograph (made without any intervention of the observer) would evidently give us the same result as though the star had electrically recorded its own passage. Further, we may particularly notice that it is immaterial whether the star was at rest, when thus seen, or in motion. Now what we have just supposed as the single case of a favorable chance among hundreds for an equatorial star; with wire intervals of one second, it will be our task to *make* occur, whatever the wire interval, and for any star observed; and that our invention may be of practical utility, to find apparatus, whose use requires no unreasonable demand on the observer's time or skill, and which is simple and portable. After numerous failures, the following apparatus was devised a year since, but it has only been constructed and put to trial with promising success at this Observatory within the last month. In the described form it is especially intended for longitude work, where it is necessary to determine the clock error from time stars (whose declination does not exceed 60°), and most desirable that the results shall be independent of that personal error in the observer, which presents itself on this class from the star's rapid motion.

On the transit pier (or in any other convenient locality) is a small clock, with a conical pendulum, whose bob slides freely up and down the graduated rod, retaining its position where left. A small horizontal wheel in the clock is controlled by the pendulum, and turns once for a certain constant number of its revolutions. This wheel revolves once for each equatorial interval of the transit wires, when the bob is set at a mark near the top of the rod, and by sliding the bob sufficiently downward; with the use of a readily-constructed table, we can, given the declination of any star between the limits 0° and ± 60°, set the pendulum, so that this wheel shall make exactly one revolution while the star passes from wire to wire. This wheel carries near its periphery a mercury drop or other contact piece, which once in a revolution is carried past a point fixed near the periphery of a stationary horizontal wheel, concentric with the first, and immediately above it, but insulated and entirely detached from it. This upper wheel, while thus related to the lower, is entirely disconnected from the machinery of the clock, and is thus far stationary, but it can be revolved by cords passing from a groove in its circumference to the hand of the observer at the transit. As the upper, or ordinarily fixed, and the lower or constantly moving, wheel have, a common vertical

axis of revolution, and as the radial distance of the point in the upper from this axis is the same as that of the contact piece on the lower, it will be seen while the upper wheel remains motionless, electric contact accompanied by a simultaneous flash, if we desire it, at the transit lantern or elsewhere, will be made at equal and uniformly recurrent epochs, the interval between which depends only on the adjustment of the pendulum. If the upper wheel be rotated forward by hand, through a small distance, and then left, the next contact will still occur, but at a later epoch, owing to the lower wheel's having to complete more than one revolution to make contact, but after this the contact and simultaneous flash will recur at the same intervals, and with the same regularity as before. If the upper wheel be moved backward, the flash will occur once, earlier, and thereafter with regularity. Moving the upper wheel, then, changes the epoch from which any series of such flashes dates and adjusting the pendulum bob, fixes the interval between subsequent flashes. In practice the lamp is removed from the transit lantern, and the two terminals of a battery or induction coil in its place, cause the flash to be thrown upon the wires, whenever the mercury drop is in contact with the point, and at the same instant a mark is made automatically on the chronograph and interpolated in the regular record of the beats of the sidereal clock, which go on in the usual way quite independently of any reference to the apparatus just described. The method of connecting the wires so as to give these results, will so readily suggest itself to the practiced observer that we need not occupy our present general description with it. I here speak of the instrument in actual use, where the contact piece makes circuit, but a break circuit is easily substituted, and we may use a Geissler tube in place of the spark.

The mode of observation will be anticipated. Before the transit of any star the observer adjusts the conical pendulum beside him (this is the work of but a few seconds), and then seats himself at the instrument holding the cords in one hand like the "reins" of an equatorial. If a flash occur just as a star is crossing the first wire (which is most unlikely) he has nothing to do, except possibly to note which was the middle wire, for each records itself on the chronograph without any intervention of his. But if the star be, for instance, two-thirds of the way from the first to the second wire at the first flash, he will draw one of the cords, accelerating the flash and thus causing the star to appear nearly coincident with the second wire when the next spark comes, and repeat the adjustment by the light of subsequent flashes, till the bisection is perfect. Three or four trials are in practice found to yield a bisection which will satisfy a fastidious eye, and when a satisfactory one

has been once made, the effect is automatically repeated. Of course, no increase in number of the wires, under these circumstances, adds real weight to that from the first satisfactory bisection, but, with the usual five tallies of five wires each, the observer can easily, if he please, obtain five independent bisections,* or one for each tally, and in this case the chronographic record corresponding to the last wire of each tally is assumed to be the significant one, unless the contrary is recorded.

Under the general conception, then, of the possibility of diminishing to any limit personal error, by employing brief views of the star or wire and utilizing the phenomena of persistence of vision, the particularly described device assumes to dispense with the observer's record upon the chronograph altogether, and to substitute a purely automatic one, giving the same virtual result as though the image of the star were a tangible object, itself making electric contact with each wire. The share of personality in any observation, is relegated to the prior act of bisecting a star, virtually motionless with relation to the bisecting wire, so that if (as seems to be the case) this act is independent of quickness or slowness of perception, of the time of cognition, or of the speed of nerve transmission; personality in the technical sense, appears not to intervene at all.

ART. IX.—*Observations of Comets made at the Litchfield Observatory of Hamilton College;* by C. H. F. PETERS.

1. *Comet* 1877, II (Winnecke's):

1877.	Mean t. H. C.			App. AR.			App. Dec.			No. of Comp.
Apr. 6.	16^h	18^m	56^s	22^h	8^m	$46{\cdot}29^s$	$+16°$	$23'$	$12{\cdot}7''$	10
" 8.	15	39	25	22	10	23·76	18	46	6·0	10
" 10.	15	25	24	22	12	13·71	21	22	7·2	10
" 12.	15	30	34	22	14	18·84	24	10	11·5	10
" 14.	14	54	27	22	16	36·48	27	7	9·8	14
" 23.	14	8	32	22	32	39·34	43	3	33·9	10
May 2.	14	0	48	23	12	23·07	62	25	28·1	10
" 12.	13	11	17	2	50	42·20	79	48	19·5	8
" 13.	12	46	23	3	38	25·44	80	10	32·7	8
" 14.	9	58	52	4	21	43·23	80	8	25·0	8
" 29.	12	2	6	8	41	1·96	+62	21	31·6	9

*I regret that this lengthy description may convey an impression of complexity as to a really very simple apparatus, all we ask of which, as a timekeeper, is that its rate shall be sensibly constant during the star's brief passage through the field. It consists only of a small conical pendulum with maintaining power and the two contact wheels described. Its installation consists in placing it in a level position and connecting it with the wires, and its size need not exceed that of the break-circuit chronometer box; it may indeed for field-work be conveniently encased with the latter.

NOTES.—This comet showed always a fine star-like concentration of light, which permitted an accurate pointing, so that the observations are good. The tail was never very bright, but the coma large. Instead of forming an envelope, as there seemed to be a tendency on April 8, the denser portion of the coma on May 2 appeared to consist of small discrete particles, exactly like a star cluster or nebula just at the point of being dissolved.

2. *Comet* 1877, III (Swift-Borelly's):

1877.	Mean t. H. C.	App. AR.	App. Decl.	No. of Comp.
May 3.	$11^h\ 6^m\ 23^s$	* — $25{\cdot}80^s$	----	6
" 3.	10 56 31	----	* $-2'\ 22{\cdot}0''$	4
" 4.	10 3 5	$5^h\ 3^m\ 25{\cdot}93$	$+60°\ 2'\ 25{\cdot}1$	8
" 5.	10 10 38	5 15 50·04	59 30 24·7	8
" 12.	10 6 41	6 29 25·59	54 7 31·2	10
" 30.	9 58 1	8 13 1·60	$+35\ 45\ 34{\cdot}3$	10

The comparison star for May 3 is D'm. $+60°$,854, and its position 1877·0 approximately $\alpha = 4^h\ 51^m\ 42^s$; $\delta = +60°31{\cdot}2$.

The observations of May 3, 4 and 5 were made by Professor J. G. Porter with the ring micrometer of the four-inch Steinheil refractor. All the other observations were obtained by myself with the filar micrometer of the 13½ inch refractor, using a power of 270, and illuminated wires.

Comet III had always a more or less blurred aspect, without distinct nucleus, rendering the pointing difficult.

Clinton, N. Y., June 1, 1877.

ART. X.—*On Complex Inorganic Acids.* From a letter of Dr. WOLCOTT GIBBS to one of the Editors, dated Cambridge, June 14th, 1877.

YOU will doubtless remember that about twelve years since Marignac described three acids which he obtained by boiling silicic hydrate, $Si(OH)_4$, with an acid alkaline tungstate, and which he called respectively silico-tungstic, tungsto-silicic and silico-deci-tungstic acid. The two first mentioned are isomeric or metameric, and are represented by the formulas:

$$12WO_3 . SiO_2 . 4OH_2, \text{ or } W_{12}O_{34}Si(OH)_8,$$

while the third has the formula

$$10WO_3 . SiO_2 . 4OH_2 \text{ or } W_{10}O_{28}Si(OH)_8.$$

It occurred to me that these results might be generalized in various ways, and I have in fact obtained some very interesting new series of acids of the same or similar types. Platinic hydrate $Pt(OH)_4$ boiled with an acid sodic tungstate yields two isomeric or metameric sodium salts which have the formula:

$$10WO_3 . PtO_2 . 4ONa_2 + 25 \text{ aq.}$$

One of these gives magnificent olive-green crystals; the other equally fine honey-yellow prisms with a very strong adamantine luster. They are readily soluble in water and give flocky or sub-crystalline precipitates with solutions of the heavy metals and of the higher alkaloids. The corresponding potassium and ammonium salts have respectively the formulas:

$$10WO_3 . PtO_2 . 4OK_2 + 9 \text{ aq. and } 10WO_3 . PtO_2 . 4OAm_2 + 12 \text{ aq.}$$

but both belong to the yellow series. I have not yet obtained the 12-atom series corresponding to Marignac's silico-tungstates. The platino-deci-tungstates dissolve tungstic hydrate, $W(OH)_6$, on boiling, but the hydrate separates again on cooling without change. Acid molybdate of sodium also dissolves platinic hydrate giving a deep olive-green solution which appears red in thick layers. The only salt of this series yet studied crystallizes in amber-colored tabular plates which have the formula:

$$10MoO_3 . PtO_2 . 4ONa_2 + 29 \text{ aq.}$$

They are very soluble and give sub-crystalline precipitates with many metallic solutions. I think I have also obtained the corresponding metameric series, but of this more in due time. The acids corresponding to the salts above briefly described are crystalline and may be obtained from the respective barium salts by sulphuric or from the silver salts by chlorhydric acid. Nearly all the salts of both series effloresce strongly and the alkaline salts have a very distinct acid reaction, so that the limit of the basicity is certainly higher than eight. I am endeavoring to generalize these results still farther by replacing platinic hydrate by other hydrates of the same type, as for instance by those of the other metals of the platinum group and by $Zr(OH)_4$. $Ti(OH)_4$, $Sn(OH)_4$, &c., but though I have in many cases indications of the formation of new complex acids I have nothing definite at present. Silico-molybdic acid appears however to be formed by boiling acid sodic molybdate with $Si(OH)_4$ when colorless or very pale yellow crystals are formed.

Nearly five years since Scheibler discovered two phospho-tungstic acids which, according to his analyses contained, respectively, six and twenty molecules of tungstic oxide, WO_3 to one of P_2O_5. As he has published nothing whatever upon the subject since, I have thought that I could fairly enter upon the same field and have begun the study of the 20-molecule series. I have already established some very important facts with respect to the compounds of this series, and have further generalized my own results to a most unusual extent.

According to my analyses, phospho-tungstic acid has the formula

$$20WO_3 . P_2O_5 . 8OH_2 \text{ or } W_{20}O_{57}P_2(OH)_{16}$$

independently of water of crystallization. I have obtained salts of this series having respectively the formulas:

$$20WO_3 . P_2O_5 . ONa_2 . 7OH_2 + 16 \text{ aq.}$$
$$20WO_3 . P_2O_5 . 2BaO . 6OH_2 + 18 \text{ aq.}$$
$$20WO_3 . P_2O_5 . 6BaO . 2OH_2 + 44 \text{ aq.}$$
$$20WO_3 . P_2O_5 . 7OK_2 . OH_2 + 27 \text{ aq.}$$
$$20WO_3 . P_2O_5 . 8OK_2 + 18 \text{ aq.}$$

All these salts have an acid reaction except the 8-molecule potassium salt, and I consider this—provisionally at least—as determining the limit of the basicity of the acid. This is important as showing that it is not phosphoric oxide, P_2O_5, which alone is saturated. Debray considered the corresponding phospho-molybdic acid as 6-basic, but written with the newer atomic weights it would of course be regarded as 12-basic, if his view were correct. He describes however a 7-atom silver salt which I should write

$$20MoO_3 . P_2O_5 . 7OAg_2 . OH_2 + 24 \text{ aq.}$$

and which is clearly the analogue of my potash salt above mentioned. All or nearly all the phospho-tungstates effloresce quickly in dry air. I regard the formulas above given as well ascertained excepting possibly that of the very acid sodium salt which heads the list. The analyses of these salts as well as of the platinum series are difficult, and the ready efflorescence is another obstacle to very precise work. All but the first mentioned sodium salt are colorless; the 7 and 8-atom potassium salts are splendid, and there is at least one ammonium salt which is precipitated as a very heavy snow-white crystalline powder. I have not used Scheibler's method of preparing these compounds, but obtain the acid sodium salt by mixing normal sodic tungstate and hydro-disodic phosphate, $WO_4Na_2 + 2$ ag. and $PO_4Na_2H + 12$ ag., in the proportion of 20 molecules of the former to 2 of the latter and adding NO_3H until the very alkaline liquid becomes acid. I have had much success in generalizing these results. The corresponding arsenio-tungstic acid and its salts are easily obtained, and I have more or less distinct indications of vanadio-tungstic and antimonio-tungstic acids. It may prove that there are also niobio-tungstic and tantalo-tungstic acids, and experiment will soon decide this point. But generalization is also possible in other ways. Thus I find that when in my process oxyfluo-tungstate of sodium, $WO_2F_4Na_2$, is substituted for the normal tungstate, splendid crystalline salts are formed with both arsenates and phosphates. In place of normal sodic arsenate the oxyfluo-arsenate may be employed and new acids result both with normal tungstate and oxyfluo-tungstate of sodium. The same statements are probably true with respect to molybdic compounds, only the resulting salts are not always well defined. You see that in this way the number of new acids is very great and that I have a heavy task before me. It is of course too soon to speculate on the theoretical structure of the new acids. I have given the simplest possible formulas in all cases, but it may be that those of the platino-tungstic and platino-molybdic acids must be doubled. In this case their analogy to the phospho-tungstates, &c., will be more easily seen, as we shall have for the sodium salts for instance,

$$20WO_3 . Pt_2O_4 . 8ONa_2, \text{ and } 20\,WO_3 . P_2O_5 . 8ONa_2,$$

meantime I have as yet seen no satisfactory reason for the change. I am disposed to think that the well known and very singular $\frac{3}{7}$ tungstates and molybdates, $3ONa_2 . 7WO_3$ and $3ONa_2 . 7MoO_3$, should be multiplied by 3 and written

$20WO_3 . WO_2 . 9ONa_2$, and $20MoO_3 . MoO_3 . 9ONa_2$.

They will then fall naturally into the 20-atom series. It seems also possible that the curious salt of Wöhler usually written $WO_4Na_2 + W_2O_5$ may be represented by such a formula as $16WO_3 . 4WO_2 . 7ONa_2$ or $W_{20} . W . O_{49}(ONa)_{14}$. I shall devote myself to these compounds until I have exhausted the subject as far as possible, and meantime anticipate many new results.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Effect of Pressure on Chemical action.*—Berthelot calls attention to Quincke's statement that in some experiments which he made in which sulphuric acid and zinc were placed in contact, the pressure of the evolved hydrogen rose in a few days from 1½ to 10 atmospheres (varying with the apparatus), in five months from 27 to 54 atmospheres, and in 17 years, from 25 to 126 atmospheres, and remarks that these experiments, made for an entirely different purpose, conclusively prove that the evolution of hydrogen is not arrested by pressure, but is only diminished in rapidity, confirming his results of twelve years ago. In this case, chemism is not modified, but only the nature and extent of the surface of attack, the metal becoming covered with an adherent gaseous layer, while the acid close to it becomes saturated. Hence, in his opinion, the evolution of hydrogen would go on indefinitely, limited in time only by the strength of the vessels containing the reagents.—*Bull. Soc. Ch.*, II, xxvii, 347, April, 1877. G. F. B.

2. *New method of determining the Specific gravity of a readily decomposable body.*—In order to determine the specific gravity of iodine trichloride, a body not only exceedingly volatile at low temperatures, but also readily dissociated except in presence of chlorine gas, Christomanos has devised a new and simple method for this purpose. In a cylindrical glass vessel closed at the ends by two suitable glass cocks and previously filled with dry chlorine gas, and weighed, the trichloride is placed and the weighing is repeated. The difference in weight is the weight of the trichloride less the weight of chlorine equal in volume to it. To determine this latter weight and thus the volume of this chlorine (which of course is the volume occupied by the trichloride) the experiment is repeated at a suitable temperature using carbon dioxide in place of chlorine. From this second difference, the known weight-relations between the gases being given, the weight of the chlorine is obtained by means of the formula $Cl = \frac{71}{27}(c_1 - b_1 - c + b)$ in which b and b_1, c and c_1 represent the first and second weighings with chlorine and carbon dioxide respectively. This weight

known, the volume is calculable at the temperature and pressure of the experiment, and hence the volume V of the trichloride is known. Its weight, $W,=\frac{27}{71(c_1-b_1)-44(c-b)}$, in grams. From these data, the density is obtained since $\frac{V}{W}=D$. The result with ICl_3 gave 3·1107, which the author thinks too high.—*Ber. Berl. Chem. Ges.*, x, 782, May, 1877. G. F. B.

3. *On the Determination of High Melting Points.*—CARNELLEY has proposed a new process for fixing the melting points of less readily fusible salts, founded on the principle that if three metallic salts A, B and C, which fuse at different temperatures such that A fuses before B and B before C, be arranged on a cold block of smooth iron and this be placed in a muffle kept at a constant high temperature, and if x be the number of seconds which elapse between the melting of A and B and y, the number of seconds between the melting of A and C, then the ratio $\frac{y}{x}$ is approximately constant for the same three salts whatever may be the temperature of the muffle, provided only it is considerably higher than that at which C fuses. Thus in sixteen experiments, using the three substances, sulphur, silver nitrate and potassium nitrate, the experiments being made at widely different temperatures, the ratio in each was 2·67, 2·68, 2·81, 2·80, 2·72, 2·67, 2·67, 2·67, 2·56, 2·62, 2·58, 2·87, 2·65, 2·88, 2·71, 2·91; mean 2·72. If the ratios obtained with different salts be reduced to the same scale, as by assuming the ratio between sulphur and potassium nitrate and any other third salt to be any given number, the value for a given salt is constant, whatever the other salts used with it in the experiment. From these ratios, time-values are obtained for nine standard salts, S, $AgNO_3$, KNO_3, $KClO_3$, TlCl, $PbCl_2$, KI, KCl, and Na_2CO_3. Thus if in four experiments, 27, 39, 45, and 65 seconds respectively elapse between the melting of S and $AgNO_3$, and 72, 106, 120, and 170 between S and KNO_3, then if we assume a constant value, say 10 seconds, for the former, the latter becomes constant; i. e., 26·7, 27·2, 26·7, 26·7 seconds. This (or the mean of a larger series 26·4) is the "time-value" for KNO_3. So 32 is the time value for $KClO_3$, 45 for TlCl, 59 for $PbCl_2$, 115 for KI, 197 for KCl, and 258 for Na_2CO_3. From the equation $\frac{y}{x}=r$, in which r is the experimental ratio for any salt, the time-value of that salt may be obtained. Thus with S, $AgNO_3$ and $KClO_3$, if $r=2·72$, $\frac{y}{x}=2·72$; whence if $x=10$, $y=27·2$, the time-value. Or, again, the value of r for $PbCl_2$, KCl and Na_2CO_3 is 1·50. Since the time-values of the two former are 59 and 197, $x=138$, and $y=207$; or Na_2CO_3 melts 207 seconds after $PbCl_2$; and since $PbCl_2$ melts 59 seconds after S, the time-value of Na_2CO_3 is 266 seconds. By accurately determining the melting points of these nine salts, and collating

them with their time-values, a table may be obtained from these data, either by direct or by graphic interpolation, from which, knowing the time-value for any salt, its melting-point can be obtained.—*Jour. Chem. Soc.*, xxxi, 365, April, 1877. G. F. B.

4. *New Vapor Density Method.*—GOLDSCHMIEDT and CIAMICIAN have modified somewhat Victor Meyer's method of fixing vapor densities, and by substituting mercury for fusible metal, have contrived an apparatus which is simple and effective. A glass bulb of 150 c.c. capacity has at its lower portion a tube which turns and passes upward to about the diameter of the bulb above it, and to which, just below its top is attached a lateral tube. A weighed substance being placed in the bulb, this is filled with mercury till it flows away by the lateral tube. The whole is placed in a bath of water or paraffin as is necessary, and heated. The production of vapor expels its volume of mercury which is received in a tarred vessel and weighed. This volume corrected is the volume of the vapor; whence its vapor is the quotient of its weight by this.—*Ber. Berl. Chem. Ges.*, x, 641, April, 1877.

G. F. B.

5. *On the Condensation of Isobutylene.*—BOUTLEROW has obtained a curious body, which he calls isodibutylene, by the action of diluted sulphuric acid upon trimethylcarbinol. It is a colorless liquid, having a boiling point between 102° and 104°, and is by its chemical characters, a hydrocarbon of the ethylene series, forming direct addition products with bromine, with hydrochloric and with hydriodic acids Moist silver oxide acts on the iodide thus obtained, giving rise to a new octyl alcohol, isodibutol, having a characteristic smell of camphor, and boiling at 146·5°–147·5°. When isodibutylene or isodibutol is oxidized with chromic acid, the principal products are acetone and trimethyl-acetic ether; hence the constitution of the hydrocarbon is represented by the formula $\begin{matrix}CH_3\\CH_3\end{matrix}\!>\!C\!=\!C\!-\!C\!\begin{matrix}\nearrow CH_3\\-CH_3\\\searrow CH_3\end{matrix}$. It is isobutylene, in which an atom of hydrogen belonging apparently to the methylene group, is replaced by tertiary butyl.—*Bull. Soc. Ch.*, II, xxvii, 370, April, 1877. G. F. B.

6. *New method of producing Salicylic acid.*—HERMANN, who studied some time ago the action of sodium on succinic ether, now finds that if the action be long continued, there is formed, probably by the action of the metal on the succinyl-succinic ether at first produced, considerable quantities of salicylic acid. The production of this substance in this way is doubly interesting; first, because since succinyl-succinic acid, whose formula is $\begin{matrix}CH_2-CO-CH.COOH\\|\\CH_2-CO-CH.COOH\end{matrix}$, is a member of the fatty series, while salicylic acid, $C_6H_4\begin{cases}COOH\\OH\end{cases}$ belongs to the aromatic, it shows a conversion of one into the other, the closed ring of six carbon atoms in the former suffering a further condensation and develop-

ing a true benzene ring; and second because from this mode of formation it is clear that in salicylic acid the hydroxyl and the carboxyl groups occupy the para position.—*Ber. Berl. Chem. Ges.*, x, 646, April, 1877. G. F. B.

7. *On the Formation of Coumarin, and of Cinnamic and other analogous acids.* — PERKIN, who synthesized coumarin $C_6H_3\begin{cases}C_2H_3O\\CO\end{cases}$ several years ago, now finds that this substance is readily produced when salicyl hydride is boiled with acetic oxide and sodium acetate. He was thus led to try other aldehydes in the same way. On boiling benzoic aldehyde with acetic oxide and sodium acetate for a day, a considerable quantity of an acid was obtained which on examination proved to be cinnamic or phenyl-acrylic acid $C_6H_5.CH.CH.COOH$. Using propionic oxide and sodium propionate, the product of the reaction was phenyl-crotonic acid, $\begin{cases}CH_2(C_2H_2C_6H_5)\\|\\CO(OH)\end{cases}$. From butyric acid and sodium butyrate, was obtained phenyl-angelic acid, $\begin{matrix}CH_2(C_3H_4.C_6H_5)\\|\\CO(OH)\end{matrix}$. From benzoic aldehyde, succinic acid and sodium succinate, isophenyl-crotonic acid. From cuminic aldehyde, acetic oxide and sodium acetate, cumenyl-acrylic or isopropylphenylacrylic acid $C_6H_4(C_3H_7).C_2H_2.COOH$, was obtained. Substituting propionic oxide gave cumenylcrotonic acid, while butyric oxide gave cumenylangelic acid. Cinnamic aldehyde with acetic oxide and sodium acetate gave cinnamenylacrylic acid, propionic oxide gave cinnamenylcrotonic acid, and butyric oxide gave cinnamenylangelic acid. Anisic aldehyde gave methylparoxyphenylacrylic, methylparoxyphenylcrotonic and methylparoxyphenylangelic acids, when thus treated. Methylsalicylic aldehyde gave methylorthoxyphenylacrylic, methylorthoxyphenylcrotonic and methylorthoxyphenylangelic acids.—*J. Chem. Soc.*, xxxi, 388, April, 1877. G. F. B.

8. *New Urea reaction.*—SCHIFF has observed that when a solution of urea in three parts of a concentrated aqueous solution of furfurol is treated with a few drops of hydrochloric acid and warmed, a splendid purple-violet color is developed.—*Ber. Berl. Chem. Ges.*, x, 773, May, 1877. G. F. B.

9. *Notes from the Chemical Laboratory of the Johns Hopkins University.* Nos. 1, 2, 3. 16 pp. 8vo: Baltimore, May, 1877.—The papers here included are: Oxidation of Mesitylene-sulphonic acid, by L. B. HALL and Professor REMSEN; on the oxidation of the Sulphoacids derived from metaxylene, by M. W. ILES and Professor REMSEN; on isomeric nitrotoluenesulphonic acids from paranitrotoluene, by E. HART and Professor REMSEN.

II. Geology and Mineralogy.

1. *Volcanic Eruptions on Hawaii;* by Rev. Titus Coan.—On the 6th and 7th of January, 1873, the great terminal pit of Mauna Loa, Mokua-weo-weo, was intensely active, exciting the attention of spectators around all the shores of Hawaii and Maui. The scene was brilliant beyond what I had ever before witnessed in that lofty crater. But it was as transient as it was bright. We were favored with only two nocturnal exhibitions, when the curtain dropped and the lights were extinguished.

On the 20th of April, 1873, this crater fired up again, and for months the illumination was grand by night, and the column of smoke and gases rose in a magnificent pillar by day.

In January, 1874, another marvellous boiling commenced in Mokua-weo-weo, and continued for fifteen months. During all this period parties could ascend the mountain, look down into this awful cauldron, listen to the surging and roaring, and startling detonations of the fiery abyss, and watch the jets as they spouted upward hundreds of feet, and the glowing waves as they rolled and dashed against the walls of the pit.

I think it was on the 11th of August, 1875, that another brilliant eruption occurred in Mokua-weo-weo, lighting up the firmament, and awakening the enthusiastic admiration of beholders. This continued but one week.

On the 13th of February, 1876, we were entertained by another grand display of Pele's fire-works, keeping thousands of people on the watch at midnight, but this also was of short duration.

All these demonstrations were confined to the great mountain crater. There were no overflowings and no lateral outbursts. The last eruption was on the 14th of last February, between 9 and 10 in the evening, and it was the sublimest scene we had ever witnessed about Mokua-weo-weo. The display of light was most glorious. It looked as if the summit of the mountain was melted, as if the heavens were on fire. Vast columns of illumined steam rose like flaming gases from the burning pit, rushing upward with fearful speed to the height of 14,000 to 17,000 feet, where it spread out into a vast fiery cloud, which shone down upon and lighting up Hilo as if the firmament were on fire, projecting shadows of the objects around. This continued through the night. In the morning the mountain had on a veil of thick clouds, the rain fell, and the gorgeous scene was hid from our eyes. After some days the clouds were dispersed, but no vestige of the marvellous scene remained. No smoke! no fire! on the mountain, but only an occasional subterranean thud, as of Vulcan's trip hammer, and a smoky atmosphere. So sudden and complete was the cessation, that all spectators were amazed and disappointed. People in Kau and Kona sent messages to Hilo, enquiring if we were having the eruption all to ourselves; and we sent back the inquiry to them, "What has become of the

volcano?" while the mountains stood above in silent and solemn grandeur. The steamer came up to Kona and to Kau, loaded with passengers, curious to witness the eruption, but the fire had become extinguished, and they returned disappointed. But before the vessel was fairly out of sight, a remarkable bubbling was seen in the sea about three miles south of Kealakekua—where Capt. Cook fell,—and a mile from the shore. Approaching the boiling pot, it was found emitting steam and throwing up pumice and light scoria, many specimens of which were gathered. This boiling was active when we last heard. It is in deep water. On the island new fissures have been opened in the pahoihoi, which extend up to the higher lands, indicating the course of a subterranean lava stream, that terminated in a submarine eruption—a new feature in our modern volcanic phenomena. About the time of this eruption beneath the sea, a tidal or earthquake wave of considerable force was observed along the coast of Kona.—*Letter to Prof. C. S. Lyman, dated Hilo, March 17th*, 1877.

2. *Geological Survey of Pennsylvania.*—The following Reports of work in this Survey have recently been issued by the Board of Commissioners, Harrisburg.

(1) *Report of Progress in the Counties of York, Adams, Cumberland and Franklin*, illustrated by maps and cross-sections showing the magnetic and micaceous ore-belt near the western edge of the Mesozoic Sandstone, and the two Azoic systems constituting the mass of the South Mountains; with a preliminary discussion of the Dillsburg Ore-bed; by PERSIFOR FRAZER, Jr. 400 pp. 8vo, with maps and sections. 1877.

(2) *Report of Progress in the Cambria and Somerset District of the Bituminous Coal-fields*, by F. and W. G. PLATT. Part I, Cambria. 194 pp. 8vo, with 44 wood-cuts and 4 maps and sections. 1877. This report gives from "the elaborate hypsometric map of Edmund Smith yet to be published," the heights of the crests of the Allegheny Mountains, showing for the western crest a range from 2,190 to 2,810 feet; and for the outer crest, 1,490 to 2,510 feet; also those of the principal summits of Laurel Hill, 2,270 to 2,450 feet.

(3) *Special Report on the Coke Manufacture of the Youghiogheny River Valley in Fayette and Westmoreland Counties, with geological notes on the Coal and Iron-ore beds*, by FRANKLIN PLATT. To which are appended a Report on methods of Coking by John Fulton, and a Report on the use of natural gas in the Iron Manufacture, by J. P. Pearse and F. Platt. 252 pp. 8vo, with maps and plates and wood-cuts.

3. *Bulletin of the U. S. Geological and Geographical Survey of the Territories.* F. V. HAYDEN, Geologist-in-Charge. Vol. III, No. 3. This number contains the following papers: Comparative vocabulary of Utah dialects, by E. A. BARBER; on methods of making Stone Weapons, by P. SCHUMACHER; by A. C. PEALE, on a peculiar type of Eruptive Mountains; by E. D. COPE, on the Geology of the Judith River and on Vertebrate fossils from the Missouri region;

C. A. WHITE, papers on Judith River group Unionidæ and Physidæ; Uniones and a new genus of fresh-water Gasteropoda from Tertiary of Wyoming and Utah; Comparison of the Unionidæ and associated mollusks with living species; paleontological characteristics of the Green River Cenozoic and Mesozoic; Dr. E. COUES, U. S. A., notes on American Insectivorous Mammals; Ornithology of source of Red River of Texas; S. AUGHEY, catalogue of land and fresh-water shells of Nebraska; A. D. WILSON, on the Geographical work of the Survey. A further notice is deferred to another number.

4. *Geological Survey of Canada*, ALFRED R. C. SELWYN, Director. Report of Progress for 1875–76. 432 pp. 8vo, with maps and plates. 1877.—This volume opens with an Introductory Report, reviewing the work of the year, by Mr. SELWYN, after which come special reports: on British Columbia, by Mr. SELWYN; on the same region, by G. M. DAWSON; and on other western areas, by Prof. MACOUN, J. F. WHITEAVES, R. W. ELLS, ROBERT BELL, and S. BARLOW; and on New Brunswick and Nova Scotia, by S. BARLOW, L. W. BAILEY, G. F. MATTHEW, R. W. ELLS, and H. FLETCHER; with a chemical Report, by C. HOFFMANN; on the Insects of the Tertiary at Quesnel, by S. H. SCUDDER; and List of Coleoptera collected on the Lower Peace and Athabasca Rivers, by Prof. J. L. LECONTE.

Mr. Selwyn states that Mr. H. G. Vennor has found a large variety of crystalline rocks in Western Quebec and Eastern Ontario, characterized by Eozoon, great beds of magnetite, apatite, and graphite; and that in Renfrew and Pontiac the labradorite rocks are interbedded with the lowest limestones; that these beds rest probably unconformably on the "Lower Laurentian or reddish gneiss.

Mr. Dawson describes the region between the Cascade Range and Fraser River, the 52d and 54th parallels of latitude. It contains extensive basaltic areas; porphyritic rocks of uncertain age; lignitic beds generally if not always beneath the basalts, which are "undoubtedly Tertiary;" Cretaceous rocks; besides gneisses, granites, diorytes, etc. The Report on New Brunswick, by Bailey and Matthew, describes the Silurian crystalline rocks of the Mascarene series, including chloritic rocks, diorytes, felsytes and argillytes. They are shown to be Upper Silurian.

5. *Shifting of the earth's axis.*—Prof. Haughton has a mathematical paper, on the shifting of the earth's axis caused by the elevation of the existing continents, in the Proceedings of the Royal Society, vol. xxvi, p. 51. He finds by calculation that the displacement would be as follows:

	Toward Greenwich. Miles.	Toward Behr. Str. Miles.	Toward Yucatan. Miles.	Toward Rangoon. Miles.
Europe and Asia,	----	58·7	199·4	----
Africa,	----	26·9	----	3·4
North America,	15·2	----	----	105·5
South America,	19·9	----	35·1	----
Australia,	----	30·2	----	30·2

The power of Europe and Asia in moving the pole is partly due to the extension of this continent along the parallel of 45°, which is the most effective latitude.

6. *Samarskite of North Carolina.*—A letter to one of the editors, from J. Lawrence Smith, dated Louisville, June 15, states that he "has succeeded in detecting and separating thoria from the North Carolina Samarskite, in which it exists to the extent of a few tenths of one per cent." And that he has discovered a new method of separating thoria from the mixed earths, easily used, and giving accurate results even when the amount present is very small.

7. *Analysis of Samarskite by Miss Ellen H. Swallow.*—The analysis of Miss Swallow (now Mrs. Professor R. H. Richards), cited on page 364 of volume xiii of this Journal, contains errors, and is therefore here given as published in the Proceedings of the Boston Society of Natural History, vol. xvii, p. 424.

Metallic acids of the tantalic group	54·96
Oxide of tin	0·16
Oxide of uranium	9·91
Oxide of iron	14·02
Oxide of manganese	0·91
Oxide of cerium (La, Di)	5·17
Yttria	12·84
Magnesia	0·52
Insoluble residue from the oxalate of cerium	1·25
Loss on ignition	0·66
	100·40

The loss was determined on another sample of the mineral.

III. Botany and Zoology.

1. *On the Development and Systematic Arrangement of the Pithophoraceæ.* By Veit Brecher Wittrock. Upsala, 1877. 4to.—In this pamphlet the writer gives an account of certain species from tropical countries, which had previously been placed in the genus *Cladophora*. Instead, however, of producing zoöspores as is the case with species of *Cladophora*, the upper portion of the cells swells and the contents pass into the swollen portion, leaving the rest empty. A cell wall is then formed, cutting off the swollen portion from the rest, and the spore is thus formed. It may be noticed as an innovation that the article is written in English. This practice is of late rather common in Scandinavia. It is to be hoped that this example will be imitated by others, since it not unfrequently happens that Swedish botanists do not receive full credit for their work, owing either to the small number of foreigners who read Swedish, or to the imperfect adaptability of Latin to modern scientific writing. W. G. F.

2. *Ueber Sprossung der Moosfrüchte und den Generationswechsel der Thallophyten.* N. Pringsheim.—An important paper, in which the writer shows that protonemata, precisely similar to the ordinary protonemata produced from the spores, may be made to

grow directly from the setæ of mosses. The latter part of the article in which Pringsheim discusses the alternation of generations in Thallophytes is excessively recondite and difficult to follow.

W. G. F.

3. *Algæ Exsiccatæ Americæ Borealis ;* curantibus W. G. Farlow, C. L. Anderson, D. C. Eaton, editæ. Fasciculus I. Bostoniæ, 1877.—Nothing helps the student of seaweeds like specimens, and fortunately in no department of botany are specimens so attractive. To help our own students and amateurs in this respect, and also to make known to foreign algologists, in an authentic way, the importance of our authors' own collections and studies in this department, they have combined to issue sets of specimens, with printed tickets, &c. This first fasciculus contains fifty species, all of real interest, many of them new or next to new, at least in collections. The specimens are full and beautiful, and the fasciculus is in every way attractively prepared. We have no announcement of the price, but we understand that a limited number of copies are to be put on sale. Professor Eaton at Yale College, Professor Farlow at Harvard, and Dr. Anderson at Santa Cruz, California, could be applied to by those who wish to obtain these sets. Algæ from the Californian coast have until now been unattainable; and those from Florida almost equally so since the late Dr. Harvey's time. The few species from our New England coast are all choice and rare, being such as *Lomentaria rosea*, *Hormactis Farlowii* of Bornet, *Lingbya Wollei*, a new fresh-water species by Farlow, *L. nigrescens*, *Calothrix crustacea* and *C. pulvinata*. Among the Californian species of Dr. Anderson's collection is Agardh's *Farlowia compressa*. A. G.

4. *Orchis rotundifolia* of Pursh, which Richardson referred to *Habenaria* (it was confidently supposed with good reason), and Lindley after him to *Platanthera*, is a genuine *Orchis*, having a pouch to the pollinia-disks as manifest as that of *O. spectabilis*. This is seen in fresh flowers of the living plant sent by Mr. Pringle from Vermont to the Cambridge Botanic Garden. A. G.

5. *Beiträge zur Entwickelungsgeschichte der Flechten. Heft. I, Ueber die geschlechtliche Fortpflanzung der Collemaceen.*—E. Stahl. Leipzig, 8vo, pp. 55.—This important contribution on the reproductive organs of lichens, forms the first portion of a work of which the author gave a preliminary notice in the Botanische Zeitung, 1874, p. 177. He has avoided any discussion of the Schwendener theory with regard to the gonidia and has sought in the study of the reproductive organs of lichens to discover their relationship to other groups. In part first, he treats of *Collema mycrophyllum* and other species of *Collema*, *Physma*, etc. The reproductive organs consist of spermatia, male, and carpogonia, female. The anatomy of the former has been known for some time, but the latter organs are now described for the first time. The carpogonia consists of two portions, the ascogone and the trichogyne. The ascogone is a coiled filament composed of several cells and is in all respects similar to the body of the same name in

the ascomycetous fungi. The trichogyne, also composed of several cells, is a more slender filament which proceeds outwards from the ascogone until it makes its way to the surface of the thallus. The experience of Stahl shows that the trichogynes seek the surface in that part of the thallus exposed to the light. In the majority of cases the spermatia and carpogonia are distinct. In the genus *Physma*, however, the ascogone is in the base of the same cavity in which the spermatia are found, a condition which Stahl maintains must prove conclusively that the spermatia are really organs of the lichen itself and not parasitic organizations as some have supposed. Stahl has often seen the spermatia attached to the exposed tip of the trichogyne, but exactly how they are attached is a difficult point to determine owing to their small size. He is inclined to believe that the process of union is similar to that which takes place in the *Florideæ*. In consequence of this union, a change takes place in the ascogone by which the asci are formed, as in the *ascomycetes*. The whole question is very candidly discussed and well illustrated by four plates. W. G. F.

6. *North American Starfishes;* Vol. V, No. 1, *of the Memoirs of the Museum of Comparative Zoology*, by ALEXANDER AGASSIZ. Cambridge, June, 1877. 137 pp. 4to, with 20 plates.—The plates, which are excellent, were drawn on stone more than twelve years ago, to illustrate a fifth volume of the Contributions to Zoölogy, by Professor Agassiz, which, unfortunately, was not completed. The first part of the volume, relating to the embryology of starfishes, was published separately by Mr. A. Agassiz in 1864, and is reprinted in the present volume with such additions as the progress of discovery has made necessary. The remainder of the volume is devoted to descriptions, especially of the hard parts, of various species (belonging to Asterias, Echinaster, Crossaster, Pycnopodia, Brisinga, Luidia, Asterina, Asteropsis, Pentaceros, Solaster, Cribrella, Astropecten) most of which are beautifully illustrated. An important chapter is also devoted to the homologies of Echinoderms. A. E. V.

7. *Ninth Annual Report on the noxious and beneficial and other insects of the State of Missouri;* by C. V. RILEY, State Entomologist. 130 pp. 8vo, with many figures and a map. Jefferson City, Mo., 1877.—Mr. Riley's report like its predecessors, is eminently practical as well as scientific. It treats of the worms that infest the Gooseberry, Currant, Strawberry and White Pine; of the Colorado Potato-Beetle, the Army Worm, the Wheat-head Army Worm, and the Rocky Mountain Locust; and also of the "innoxious Insects" the Hellgrammite and Yucca Borer. Of the Colorado beetle Mr. Riley remarks that its eastward progress was at the average rate of eighty-eight miles a year (though not over fifty miles a year over the region west of the Mississippi), and that it has now invaded nearly 1,500,000 square miles, or more than one-third the area of the United States. It does not thrive where the thermometer reaches near 100° F., and hence "it may never extend its range very far south of the territory now occupied;" but its northern spread is not limited, and it may push to the

northernmost limit of the potato-growing country—a limit which it has already well nigh reached. It travels by means of wings. But "it undoubtedly availed itself to no considerable extent, of every means of transportation afforded to other travelers, and often got a lift on eastward bound trains; and it most probably crossed the more barren plains bordering its native confines through man's direct agency, that is, by being carried." "Even the winds and waters aided its progress."

8. *Bulletin of the U. S. Entomological Commission—U. S. Geol. and Geogr. Survey*,—No. 1, 12 pp. and No. 2, 14 pp. 8vo.—The Entomological Commission consists of C. V. RILEY, A. S. PACKARD, Jr., and CYRUS THOMAS. Their first bulletin treats of the methods of destruction of the young or unfledged locusts; and No. 2 of their natural history and habits in the young unfledged state, with wood-cuts, and a map of the region east of the Rocky Mountains overrun by the insect.

IV. ASTRONOMY.

1. *Astronomical and Meteorological Observations made during the year* 1874 *at the U. S. N. Observatory, Rear-Admiral* DAVIS, *Supt.* Washington, 1877.—This volume contains the observations of the year 1874 at the Naval Observatory, with the reduced results. The astronomical work has been mostly done by means of the three instruments, the transit circle, the 26-inch equatorial, and the mural circle. The latter instrument has been under the charge of Prof. Yarnall, who is preparing a revised edition of the general catalogue of stars observed at the Observatory. There are two appendices to the volume: I. Instruments and Publications of the U. S. N. Observatory (see p. 242, vol. xiii, of this Journal), illustrated with heliotypes of the instruments; II. Report on the difference of longitude between Washington and Ogden, Utah, by Professor Eastman. This difference is found to be $2^h\ 19^m\ 47^s{\cdot}41$. H. A. N.

2. *Relative ages of the Sun and certain fixed Stars.*—Professor KIRKWOOD closes a communication upon this subject to the American Philosophical Society with the following summary of his conclusions:

(1.) The history of the solar system is comprised within twenty or thirty millions of years.

(2.) From the fact that the larger component of Alpha Centauri radiates twice as much light as the sun while the mass of the former is *less* than that of the latter, we infer the probability that our solar system is the more advanced in its physical history.

(3.) 61 Cygni seems to have reached a greater degree of condensation than the sun, since, on the hypothesis of equal density, the surface of the larger member is one-third that of the sun, while the intrinsic light is less than one-ninth.

(4.) The companion of Sirius appears to have reached a stage of greater maturity than the sun, while the contrary seems to be true in regard to the principal star. H. A. N.

3. *Annals of the Astronomical Observatory of Harvard College.* Vols. VIII and X.—The first seven volumes of the Annals of the Astronomical Observatory of Harvard College contained the results of the work done under its first two Directors, W. C. Bond and G. P. Bond.

Three catalogues gave the observed places of 16,084 stars observed in zones between the equator and 1° N. declination. The great comet of 1858, the nebula of Orion, and spots on the sun, each filled a volume, and the planet Saturn filled one part of a volume. The second part of vol. IV has not yet appeared, but is in course of publication. The eighth volume contains in its first part an historical account of the Observatory from 1855 to 1876, and is richly illustrated by engravings of the instruments and apparatus of the Observatory. The second portion consists of the "Engravings from the Observatory of Harvard College," which has been furnished separately to subscribers, and has been heretofore noticed in this Journal. They are thirty-five in number (making more than fifty engravings in the volume), and constitute a most valuable contribution to Descriptive Astronomy. The tenth volume of the Annals contains the first portion of the work, with the new Meridian Circle under Prof. Winlock. The observations were made in 1871 and 1872 by Prof. W. A. Rogers, aided by Mr. A. McConnel, and the reduction of them and the editing of the volume was by Prof. Rogers. There were 564 stars observed, mostly bright ones. The introduction contains an elaborate comparison of these observations with the places given for the same stars in twenty-seven earlier catalogues. The volume concludes with three catalogues: 1st, of 289 primary stars, being those which are in the list of fundamental stars of the Astron. Gesellschaft; 2d, of the 275 stars not in that list; 3d, of about 600 stars observed in R. A. in 1867 and 1868, with the transit circle, by Mr. E. P. Austin. H. A. N.

4. *Meteoric Fireballs.*—Professor Kirkwood gives an account of eight large bolides between July, 1876 and February, 1877, to the American Philosophical Society. The more important ones have been noticed in this Journal, except one of July 8th, 1876, at $8^h\ 45^m$ P. M., which from an altitude of 88 miles passed N. 78° W. across the N. E. corner of Indiana, and exploded over Lake Michigan at a height of 34 miles. The path was inclined 21° to the horizon; no detonation reported; train visible 40 minutes.

5. *On the part of the motion of the lunar perigee which is a function of the mean motions of the Sun and Moon;* by G. W. Hill. Cambridge, 1877. 4°, pp. 28.—The motion of the lunar perigee as observed does not agree with any of those computed by theory within the limits of error of the observations. This may be due to not carrying the approximations far enough and the author undertakes to compute its value, so far as it depends on the mean motions of the sun and moon, with a degree of accuracy that shall leave nothing further to be desired.

6. *Chicago Observatory.*—Referring to the statement of Mr. Burnham in this number (p. 31) we beg of the friends of science in Chicago to see if it is not possible to secure for him in some way the use of the telescope in the Observatory. For many years this large instrument (for a part of the time the largest refractor in the world) has lain idle, not at all to the credit of Chicago. It should have been steadily doing service in astronomy, such service as almost no other instrument can do. Mr. Burnham has shown that he can do good work, and the friends of science everywhere have a right to complain that the instrument lies idle when he is willing to use it.

7. *The Observatory, a Monthly Review of Astronomy.* Edited by W. H. M. CHRISTIE, M.A. Nos. 1 and 2, April and May.—This is a new monthly of thirty-two pages, published by Taylor & Francis, London. For convenience of American subscribers currency will be received at the rate of one dollar for three months' subscription. These two numbers contain accounts of the April and May meetings of the Royal Astr. Soc.; and the following besides other articles: Photographic Spectra of Stars, by W. Huggins; Determination of the Solar Parallax, by D. Gill; the Twinkling of the Stars, by E. Ledger; also Notes, Correspondence, Memoranda, Ephemerides, &c.

8. *An Elementary Treatise on Elliptic Functions;* by ARTHUR CAYLEY. Deighton, Bell & Co. Cambridge and London. 8°, 1876.—There has been hitherto no elementary separate treatise in English upon elliptic functions. The thanks of mathematicians are due to Professor Cayley for supplying the want. An excellent feature of the book is the *general outline* which fills the first chapter.

V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association.*—The American Association will hold its twenty-sixth meeting in Nashville, during the week commencing with the 29th of August. The Local Committee is making arrangements for the private entertainment of the members where they may desire it, and also for free return tickets as far as practicable, besides providing, by means of excursions and in other ways, for the pleasure and profit of those who shall be present. The president of the meeting is SIMON NEWCOMB, of Washington, and the vice-presidents, EDWARD C. PICKERING, of Cambridge and O. C. MARSH, of New Haven. Mr. J. Berrien Lindsley is Secretary of the Local Committee.

2. *New American Scientific Museums.*—A bill to establish a Historical Library and Natural History Museum at Springfield, Illinois, has been passed by the Legislature of the State. It appropriates to it one of the large halls of the New Capitol building. The valuable collections made in connection with the geological survey of the State, many specimens of which are the types of new species described in the volumes of Reports, will here have safe

keeping. Professor Worthen writes, that about it will be built up an institution of science that will be an important addition to the educational resources of the West.

At St. Louis, Missouri, the "St. Louis Museum of Arts and Sciences" has recently been instituted. It includes among its officers the names of prominent men of science of Missouri, and promises to be a center of great scientific activity.

3. *Earthquake oceanic wave of May 9th and 10th*, 1877.—The Monthly Weather Review for May, published by the Signal Service under Gen. Albert J. Mayer, contains many details respecting this earthquake wave, and a table of data for estimating approximately the velocity. About 8.50 P. M. of May 9th, heavy earthquake shocks were felt over the region between Arica and Mexillones (border of Peru and Bolivia). The oceanic wave which immediately followed was of great violence along the adjoining South American coast, and was felt also as far north as California, the rise at Anaheim (33° 8′), being 12 feet in a few minutes. The wave at Callao, Peru, was felt at 11 P. M.; at San Francisco, perceptible at 6^h 18′ A. M., May 10, and 14 inches in rise (maximum) at 8^h 20′; the Sandwich Islands, on eastern Hawaii, at Hilo, at 4 A. M., and the great wave, 36 feet high, came in at 4^h 45′; at Honolulu, first felt at 4^h 45′, and the great wave at 5^h.

Rev. T. Coan, in a letter to one of the editors dated May 11, states that "thirty-six hours subsequent to the catastrophe at Hilo, the pulsations of the tidal wave still continued, the incoming and outflowing wave occupying about an hour, the latter leaving the channels nearly bare."

4. *A practical Treatise on Lightning Protection;* by HENRY W. SPANG. 180 pp. 12°. Philadelphia, 1877. (Claxton, Remsen & Haffelfinger.)—This treatise discusses the various questions that arise in the construction of lightning rods, and their application to different kinds of structures. The great defect of most lightning rods, that of imperfect earth connections, with the remedies, are very fully treated. The directions are such that an intelligent mechanic can carry them into effect.

With many minor statements of the author we should not agree. Thus (p. 176) he says, "a building over 100 feet square cannot be properly protected unless in addition to the conductors and earth-terminals upon the outside thereof, a suitable number of conductors are employed through the interior, etc." The book, however, as a whole, is one to be heartily commended.

5. *Natural Philosophy for Beginners;* Part I, *the Properties of Solid and Fluid Bodies;* by I. TODHUNTER, M.A., F.R.S. 368 pp. small 8vo. London, 1877. (MacMillan & Co.)—The character of this little work will be best understood by the following quotation from the author's preface:—"The design of the work is to furnish a simple and trustworthy manual for those who are beginning the study of natural philosophy; and it ventures to claim a distinct position among the numerous publications

which have appeared with somewhat similar aims. On the one hand great pains have been taken to render the book intelligible to early students; the amount of mathematical knowledge assumed is merely a familiarity with the elements of arithmetic. On the other hand the subject is presented, it may be hoped, with adequate fullness, so that a person who has mastered the work will have gained considerable acquaintance with the principles of natural philosophy. Moreover, a collection of examples for exercise (above 500 in number) is added." The many excellent textbooks of Prof. Todhunter are now so well known that it is unnecessary to add more than a general commendation of the manner in which the author's plan, as above expressed, has been carried out. The second part of the work is now in the press.

6. *Third Biennial Report of the Vermont Board of Agriculture, Manufactures and Mining, for the years* 1875–76. By HENRY M. SEELY, Secretary of the Board. 704 pp. 8vo. Rutland, 1876.—This volume is made up of brief original reports by various citizens of Vermont on topics of general interest connected especially with agriculture, and to some extent with manufactures. Among the interesting chapters there is one on the relation of bees to fruit culture, by J. E. Crane, of Bridport; others —on an analysis of fertilizers, by Prof. Seely; Pisciculture with reference to farming, by G. B. French, of Woodstock; Experiments in the hybridization of cereals, by C. G. Pringle, of Charlotte; Insects injurious to the potato and apple, by Prof. G. H. Perkins.

7. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters.* Vol. III, 1875–76. 270 pp. 8vo. Madison, Wisconsin.—Among the original scientific papers in this volume there are the following: Kaolin in Wisconsin, by R. Irving; on the Geology of Northern Wisconsin, by E. T. Sweet; on some of the small lakes of Wisconsin, by I. A. Lapham; on Copper tools found in Wisconsin, by J. D. Butler; Report of Committee on Exploration of Indian Mounds in the vicinity of Madison.

8. *Journal of the Academy of Natural Sciences of Philadelphia*, Vol. VIII, part 2.—This part contains papers on Batrachia and Reptilia of Costa Rica and elsewhere, by E. D. Cope; on the Ichthyology of Lake Titicaca, by the same; and a descriptive catalogue of the Scalidæ of the West India Islands, by O. A. L. Mörch.

Manchester Science Lectures for the People. Eighth series, 1876–77, in pamphlets of 45 to 64 pages, 12mo.—Why the Earth's Chemistry is as it is; three lectures by J. NORMAN LOCKYER, F.R.S.; 60 pp.—The Succession of Life on the Earth; three lectures by Professor W. C. WILLIAMSON, F.R.S.; 62 pp.—Technical Chemistry, by Professor ROSCOE, F.R.S., 46 pp. Macmillan & Co., London and New York.

OBITUARY.

ELKANAH BILLINGS.—The decease of Mr. Billings a year since, at Montreal, was announced in this Journal, in volume xii, at page 80. We are indebted to his successor as paleontologist in the Canada Geological Survey, Mr. J. F. Whiteaves, for the following facts connected with his labors in science.

Mr. Billings was born near Ottawa City, on the 5th of May, 1820, and died on the 14th of June, 1876. In 1839 he commenced the study of law, and for seven years, beginning with 1844, his pursuit was that of a barrister. For the four years following he added the duties of editor of the "Ottowa Citizen." But between 1852 and 1856 a large proportion of his time was devoted to the collection and study of the Lower Silurian fossils of the country about Ottawa City, and this brought him into familiar correspondence with Sir William Logan, and led to his appointment, in 1856, to the position of paleontologist of the Geological Survey of Canada. He had been elected a member of the Canadian Institute of Toronto in 1854, and published the same year, in its Journal, his first paleontological paper—"On some Genera and Species of Cystidea from the Trenton limestone." In 1856, he commenced the publication of the "Canadian Naturalist and Geologist;" but he was relieved of the responsibility of editor the following year by a committee of the Natural History Society of Montreal, while continuing to be a large contributor to its pages. With the exception of part of the year 1858, which was spent in Great Britain and Paris, studying and comparing such foreign and North American British fossils as threw light on Canadian species, the remainder of his life was passed at Montreal, in the study of the Canadian collections, and in excursions among the fossiliferous rocks of Canada and adjoining portions of the United States. Besides numerous papers contributed to the Canadian Journal of Toronto, the Canadian Naturalist of Montreal, the Geological Magazine, and to the pages of this Journal, he published the following more extended memoirs: An illustrated monograph of Lower Silurian Cystidea and Asteriadæ, and on the Crinoidea of the same formation: these two memoirs constituting Decades 3 and 4 of "Canadian Organic Remains;" Palæozoic Fossils, vol. i, 526 pp. 8vo, with numerous figures, 1865, and vol. ii, part 1, 144 pp. 8vo, with nine plates and many wood-cuts, 1874; and "Catalogues of the Silurian Fossils of the Island of Anticosti."

Mr. Billings's knowledge of the invertebrates of the Silurian and Devonian formations was extensive and profound, and his descriptions of fossils are both lucid and scrupulously accurate. To his critical acumen we are indebted for a very considerable part of our knowledge of American paleontology; and especially for his elaboration of the remarkable, and still somewhat enigmatical, fauna of the Quebec Group, of the south shore of the St. Lawrence, in Eastern Canada, and of the northern extremity of Newfoundland. His paper "on the remains of the Fossil Elephant found in Canada,"* and another on the bones of a Beluga dug up at Cornwall (Ontario),† show that he was well versed in comparative osteology, and many of his earlier contributions to the "Canadian Naturalist" bear witness to the eagerness with which he prose-

* Canadian Naturalist, First Series, vol. viii, 1863.

† Read before the Natural History Society of Montreal, but never published.

cuted his zoological studies. Entomology and mineralogy were favorite departments of science with him, and he made at one time a tolerably complete collection of Canadian Coleoptera, which he presented to the Natural History Society of Montreal a few years before his death.

For many years Mr. Billings was one of the Vice-Presidents of the Natural History Society of Montreal. He was frequently pressed to accept the office of President, but invariably declined. He was elected a Fellow of the Geological Society of London in 1858. The silver medal of the Montreal Natural History Society was voted him by the members at the annual meeting held in 1867, by way of testifying to their appreciation of "his long continued and successful labors for the promotion of science in Canada."

Mr. Billings possessed great firmness and strength of character coupled with a winning simplicity of manner and unaffected modesty. To these traits were added inflexible love of truth and justice, disinterested and self-sacrificing zeal for the acquisition of knowledge, and untiring industry in his pursuits.

In 1845 Mr. Billings married a sister of Mr. Wilson, of Toronto, now the Hon. Judge Wilson, but then the junior partner in the legal firm of Messrs. Baldwin & Wilson, in whose office he studied the last year prior to his being called to the bar. Since his decease the members of the Natural History Society of Montreal have passed resolutions expressing their high estimation of his personal character and writings; and a few of his more intimate friends in the society have subscribed for a fine life-sized portrait of their distinguished associate, which now adorns its lecture room.

Colonel Ezekiel Jewett, died at Santa Barbara, Cal., May 18th, aged 86. He was born at Rindge, N. H., Oct. 16, 1791. He was an officer in the U. S. army in the war of 1812, and afterward took part in the Chilian war, under Gen. Carrera. He has long been well known to geologists and conchologists as an enthusiastic and indefatigable collector of fossils and shells. An extensive geological collection, made by him, is now the property of Cornell University. For several years past he has devoted himself entirely to conchology and had accumulated a valuable collection of shells, embracing over 12,000 species. He collected extensively on the west coast of Florida.

Dr. Philip P. Carpenter, one of the ablest modern conchologists, well known especially for his several excellent works on the mollusca of the west coast of North America, died at Montreal, May 24th, aged fifty-eight. A more extended notice is necessarily deferred to another number.

Robert Dale Owen, died on the 24th of June, at his summer residence on Lake George, at the age of seventy-six.

APPENDIX.

ART. XI. — *Principal Characters of the Coryphodontidæ;* by Professor O. C. MARSH. With plate IV.

NEAR the base of the Eocene, in the Rocky Mountain region, are numerous remains of a well marked group of mammals which the writer has termed the *Coryphodontidæ*.* These animals are of peculiar interest, both on account of their structure and affinities, and especially as they are among the oldest of Tertiary Mammals, and mark a definite geological horizon in this country and Europe. Only the single genus, *Coryphodon*, is known, and this was established, in 1846, by Owen, who described a characteristic fragment of a lower jaw from the London Clay of England.† Other imperfect specimens were subsequently found in France, and fully described by Hébert,‡ but up to the present time very little is known of this genus from European specimens.

The identification of the American remains with the genus *Coryphodon* of Owen, and the determination thereby of a definite horizon, common to the two countries, and containing the oldest known Tertiary Mammals, was published by the writer in April, 1876, and subsequently in the following number of this Journal (vol. xi, p. 425.)§

The Museum of Yale College contains a large collection of *Coryphodon* remains from Utah, Wyoming, and New Mexico, and this material is amply sufficient to indicate all the more important characters of the group. Among these specimens are portions of the same individuals described by Cope under the names *Bathmodon* and *Loxolophodon*,‖ both of which are synonyms of *Coryphodon*, as the remains on which they were based clearly belong to that genus. One of the species best represented in the Yale collection is *Coryphodon hamatus* Marsh, and this has afforded many of the characters given below.

* This Journal, vol. xi, p. 428, May, 1876.

† British Fossil Mammals and Birds, p. 299.

‡ Annales des Sciences Naturelles, tome vi, p. 87, 1856.

§ In the American Naturalist (vol. xi, p. 95), Prof. Cope has recently claimed this discovery on the strength of a paper which he read before the Spring Meeting of the National Academy, in 1876. He knew, however, at the time that my article was already published, and during the reading of his paper, a printed copy of my publication was in the room, in the hands of a member.

‖ Proceedings American Philosophical Society, 1872, p. 420.

The skull of *Coryphodon*, in all its more important characters, is of the perissodactyl type. It is elongated, and the facial portion is most produced. A line drawn from the lower margin of the foramen magnum along the palate is nearly straight. The zygomatic arches are expanded, but the malar is comparatively slender, and unites with the maxillary in front of the orbit. The general form of the skull is shown in the accompanying plate, figure 1. The maxillaries are massive, and usually deeply indented on the sides behind the canines. The lachrymal forms the anterior border of the orbit, and its foramen is inside the orbital margin. The nasals are slender in front, and broad posteriorly. The premaxillaries are expanded transversely, and the narial aperture is wide. The occipital condyles are well separated, and there are condylar foramina. Between the basisphenoid and the periotic, there is a large opening. There is a paroccipital, and a post-glenoid process.

The dental formula of *Coryphodon* is as follows:

$$\text{Incisors } \frac{3}{3};\ \text{canines } \frac{1}{1};\ \text{premolars } \frac{4}{4};\ \text{molars } \frac{3}{3};\ \times 2 = 44.$$

The teeth in American specimens do not differ essentially from those described by Owen and Hébert, which are well represented in the memoir of the latter author, cited above.

The brain cavity in *Coryphodon* is perhaps the most remarkable feature in the genus, and indicates that the brain itself was of a very inferior type. It was quite small, as in all Eocene mammals, but its most striking features were the small size of the hemispheres, and the expanded cerebellum. The form and relative size of these are shown in the accompanying plate, figure 1.

The olfactory lobes were large, and entirely in advance of the hemispheres. They were bounded in front by a well ossified cribriform plate, and partially separated by a vertical bony septum. The cerebral lobes were ovate in form, and very small, a transverse section exceeding but little that of the medullar opening. In shape and relative size, the hemispheres and olfactory lobes of this genus are somewhat similar to those of *Dinoceras*. The cerebellum was proportionally large, and widely expanded transversely. Its peculiar form is shown in figure 1, which is drawn from a cast of the brain-cavity of *C. hamatus*. This portion of the brain nearly or quite equaled the hemispheres in size, thus differing widely from any known mammal. There is a well marked pituitary fossa, but no clinoid process. The foramina for the exit of the optic nerves are small, but for the others very large. The brain as a whole was very low in grade, and precisely such as might be expected in a mammal from the oldest Tertiary deposits.

These essential characters of the brain of *Coryphodon* were determined and published by the writer more than a year ago, with figures of a very perfect cast of the brain-cavity. (This Journal, vol. xi, p. 427.) Two skulls, in remarkable preservation, were examined during the investigation, and the results have since been confirmed by other specimens in the Yale Museum.

These facts are important, since Cope has recently published a paper on the same subject, and given descriptions and figures of the brain case of *Coryphodon* which differ materially from my own.* He makes no reference to my article, although perfectly familiar with it. A comparison of his figures with the specimens mentioned above, shows at once that he has made most serious mistakes in his observations. What he represents as olfactory lobes, are unlike anything in nature, and are merely a cast from an imperfect skull in which the mesethmoid septum, and the cribriform plate are both evidently imperfect or wanting. Similar errors are apparent in other portions of the figures, and his classification, based on these and like observations, is untenable, as the known facts are against it.

The vertebræ of *Coryphodon*, in their more important characters, resemble those of *Dinoceras*. The cervicals are proportionately longer. The odontoid process of the axis is a short peg. The articular faces of the cervicals and dorsals are nearly flat. The caudals indicate a tail of moderate length.

The limbs of *Coryphodon* were comparatively short. The scapula is acuminate above, as in *Dinoceras* and the Elephant. The humerus is much less massive than in *Dinoceras*, but otherwise resembles it. The deltoid ridge extends beyond the middle of the shaft. The distal end of the humerus is compressed antero-posteriorly, and the ulnar side of the articulation is much more prominent than the radial, thus approaching the Rhinoceros where it departs from *Dinoceras*. The radius is proximally smaller, compared with the ulna, than in Rhinoceros. Its distal end is larger than that of the ulna.

The femur of *Coryphodon* is of the perissodactyl type, and has a distinct third trochanter. The tibia, when in position, was not in the same line with the femur, as in *Dinoceras* and the Elephant, but was inclined at a moderate angle. The fibula was entire, and its distal end articulated with both the astragalus and calcaneum.

The feet of *Coryphodon*, hitherto essentially unknown, resemble most nearly those of *Dinoceras*, and can perhaps be best illustrated by a direct comparision with them. In the following figures (see plate iv), the feet of these two genera are placed side by side, and in the same position. The main points of difference between them are stated below.

* Proceedings American Philosophical Society, p. 616, 1877.

The manus and pes of *Coryphodon* had each five short digits. The carpal bones are shorter, measured in the line of the foot, than in *Dinoceras*, and the distal row present more curved articular faces to the metacarpal bones, indicating greater freedom of motion. The pyramidal is destitute of the tubercle projecting outward and forward for the support of the fifth digit, seen in *Dinoceras*. The metapodial bones and phalanges are throughout less roughened and tubercular than in *Dinoceras*, and all their articular faces indicate greater flexibility in the feet. The ungual phalanges expand laterally for the support of the hoofs, instead of being rounded, as in *Dinoceras*.

In the hind foot, the astragalus, and in a less degree the cuboid and navicular bones are shorter, along the line of the foot, than the corresponding bones of *Dinoceras*. The astragalus has the tibial articulation less convex, and the fibular articulation more extensive, covering the whole exterior or fibular side of the bone. The navicular and cuboid faces are more distinctly separated, and make a greater angle with each other than in *Dinoceras*. The calcaneum approaches the ordinary perissodactyl type, the shaft being much longer than in *Dinoceras*, and the tubercular surface below for the support of a plantar pad, seen in the Elephant and *Dinoceras*, is undeveloped. The cuboid is of peculiar shape, being sub-triangular. The calcaneal face is long and oblique, reaching nearly to the face for the fifth metatarsal. Both the metatarsal articulations are essentially in one plane, and are separated only by a very slight ridge. The navicular articulates very slightly, if at all, with the cuboid, but covers the face of the astragalus, and fully supports the ectocuneiform. The latter bone is not at all supported by the astragalus, as asserted by Cope (Catalogue of Vertebrata of the Eocene of New Mexico, p. 27). He has also published a remarkable figure of the hind foot of *Coryphodon* (Bathmodon), showing the hallux with three phalanges, and the fifth digit reduced to a rudiment (loc. cit., p. 28).

The average size of the animals of this genus was about that of the existing Tapir. Some were smaller, and others nearly twice as large. Their mode of life was probably similar.

A careful consideration of the characters of *Coryphodon*, so far as now known, indicates that the genus represents a distinct family of perissodactyl Ungulates, the *Coryphodontidæ*. The skull is clearly of this type, and the skeleton and feet present no differences sufficiently important to justify a separation from that natural order. Only a slight modification of the limits of the *Perissodactyla*, would bring this five-toed genus into it, and simplify classification.

The geological horizon of *Coryphodon* in this country is near the base of the Eocene, in the strata named by the Survey of

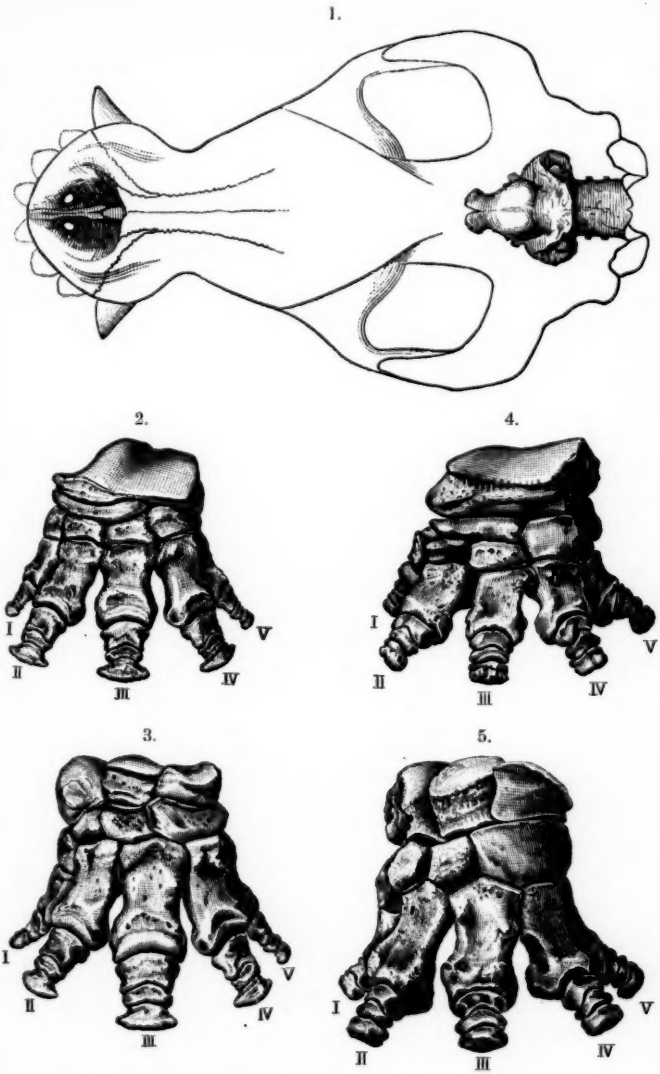


Figure 1.—Outline of skull and brain-cavity of *Coryphodon hamatus* Marsh; top view. About one-fifth natural size.
Figure 2.—Hind foot of *Coryphodon;* front view.
Figure 3.—Fore foot of *Coryphodon;* front view. Both one-third natural size.
Figure 4.—Hind foot of *Dinoceras;* front view.
Figure 5.—Fore foot of *Dinoceras;* front view. Both one-fifth natural size.

the Fortieth Parallel, under Clarence King, the Vermillion Creek series, and by Hayden the Wasatch group. The known localities are in Utah, Wyoming and New Mexico. Among the associate mammals are the equine *Eohippus*, and the suilline *Helohyus*, showing clearly that we must look to Cretaceous strata at least for the parent form of the Ungulates.

Yale College, June 12th, 1877.

ART. XII.—*Characters of the Odontornithes, with Notice of a new allied Genus;* by Professor O. C. MARSH. With plate V.

THE Cretaceous birds with teeth, (*Odontornithes*), described by the writer, prove on careful investigation to possess some important characters in addition to those already published.* This is especially true of *Hesperornis*, which is now represented in the Yale College Museum by so large a number of specimens that almost every part of the skeleton is known, and all the more important points in its structure have been determined.

The most marked features in this genus already announced, are: the teeth in grooves; sternum without keel, and rudimentary wings; and posterior limbs closely resembling those of modern diving birds. The last character, which seemed at first sight to indicate the near affinity of *Hesperornis* with the *Colymbidæ*, proves to be only an adaptation; while the skull, scapular arch, and other important portions show unmistakably that the nearest existing allies of the genus are the *Ratitæ*, or Ostrich group, the most reptilian of modern birds. The characters that show this affinity are nearly identical with those laid down to distinguish the *Ratitæ* by Huxley in his important memoir on the Classification of Birds.† They may be briefly stated as follows:

1. The sternum is devoid of a crest.

2. The long axes of the adjacent parts of the scapula and coracoid are parallel, or identical.

3. The posterior ends of the palatines, and the anterior ends of the pterygoid are very imperfectly, or not at all, articulated with the basisphenoid rostrum.

4. Strong "basipterygoid" processes, arising from the body of the basisphenoid, and not from the rostrum, articulate with facets which are situated nearer the posterior than the anterior ends of the inner edges of the pterygoid bones.

5. The upper, or proximal, articular head of the quadrate bone is not divided into two distinct facets.

* This Journal. vol. x, p. 403, Nov., 1875.

† Proceedings Zoological Society, 1867, p. 448.

The vomers are separate, as in lizards and a few modern birds. In the pelvic arch, the ilium, ischium and pubis are free at their distal ends, as in the Emu, and the acetabulum is perforated only by a moderate foramen.

The scapular arch of *Hesperornis* is represented in plate V, figure 1. Its position in the skeleton is shown in the restoration, figure 2.

The scapula is long and slender, and has no acromial process. The clavicles are separate, but meet on the median line, as in some very young existing birds. The coracoids are short, and much expanded where they join the sternum. The latter has no distinct manubrium, and is entirely without a keel. The wings were represented by the humerus only, which is long and slender, and without any trace of articulation at its distal end. Its position was close to the ribs, and it was probably nearly or quite concealed beneath the integuments, as in *Apteryx*. This rendered the rudimentary wings of no possible service in flight or swimming.

Baptornis advenus, gen. et sp. nov.

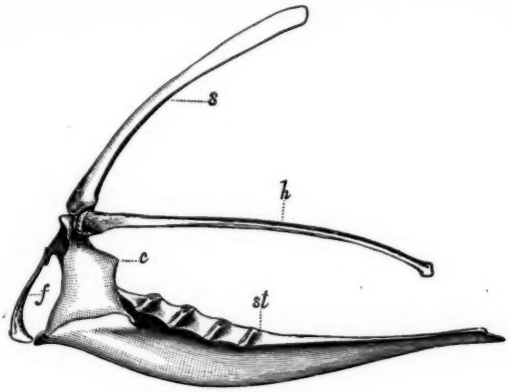
The existence of a small swimming bird cotemporary with *Hesperornis* is indicated by a nearly perfect tarso-metatarsal bone from the same geological horizon. This specimen, although pertaining to a bird not fully adult, is in excellent preservation, and is so characteristic that it may be readily distinguished from any forms already described.

In general shape and proportions, this bone most nearly resembles the corresponding part in *Hesperornis*, but differs from it decidedly in the outer metatarsal, which at its lower end scarcely equals the adjoining one in size and length. In *Hesperornis*, on the contrary, the outer metatarsal is more than double the size of the third. In the present specimen, the three trochlear articulations of the distal ends are nearly equal. The existence of a hallux is indicated by a small elongated depression on the inner metatarsal, a short distance above the articulation. As in *Hesperornis*, there are no canals or grooves for tendons on the posterior face of the proximal end.

The principal dimensions of this tarso-metatarsal are as follows:—

Entire length	76· mm
Transverse diameter of proximal end	17·
Antero-posterior diameter	8·
Length of second metatarsal	64·5
Length of third metatarsal	72·
Length of fourth metatarsal	72·
Antero-posterior diameter of distal articulation of second metatarsal	8·5

1.



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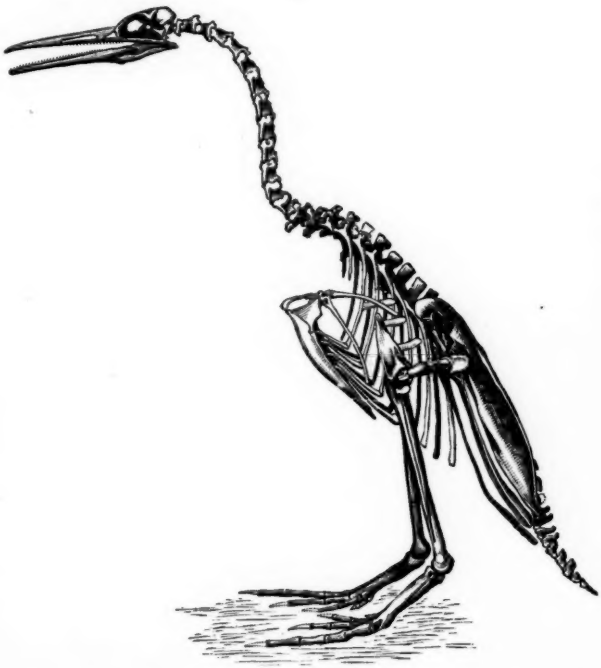


Figure 1. Scapular arch of *Hesperornis regalis* Marsh, one-half natural size. *s.* scapula; *h.* humerus; *f.* furculum; *c.* coracoid; *st* sternum.
Figure 2. Restoration of *Hesperornis regalis*, about one-tenth natural size.

Transverse diameter	5· mm
Antero-posterior diameter of distal articulation of third metatarsal	9·2
Transverse diameter	6·
Antero-posterior diameter of distal articulation of fourth metatarsal	9·
Transverse diameter	5·5

This specimen indicates a bird about as large as a loon, and apparently of similar habits. The locality of the only remains at present known is in Western Kansas, in the same Cretaceous beds that contain the *Odontornithes* and *Pteranodontia*.

ART. XIII.—*Notice of a new and Gigantic Dinosaur;* by Professor O. C. MARSH.

THE Museum of Yale College has recently received from the Cretaceous deposits of Colorado a collection of reptilian remains of much interest. Among these specimens are portions of an enormous Dinosaur, which surpassed in magnitude any land animal hitherto discovered. The most characteristic bones preserved are portions of the sacrum, and posterior limbs. The former is represented by the last two vertebræ with their transverse processes, nearly complete, and by other fragments. The last sacral vertebra has its centrum moderately concave below on each side of the median line, but only near its anterior end can indications of a keel be observed. The next sacral vertebra has its inferior lateral surface so deeply concave as to materially lessen its bulk. This is also true of the next anterior centrum, and may be considered a distinctive character of these vertebræ. A more important character of the same centra is a very large cavity in each side, connected with the outer surface by an elongated foramen, below the base of the neural arch. The inner surface of this cavity indicates that it was not filled by cartilage, and it probably was a pneumatic opening, designed to lessen the weight of the enormous sacral mass. The transverse processes of these vertebræ are very stout, and of moderate length. Their distal ends are firmly coössified, forming a powerful support for the ilium. Between these processes are large oval openings.

The following measurements give the more important dimensions of these interesting fossils:

Length of centrum of last sacral vertebra	300· mm
Transverse diameter of distal end	270·
Vertical diameter of distal end	250·
Distance between extremities of transverse processes	850·

Length (approximate) of next sacral vertebra	280·	mm
Transverse diameter of posterior end	200·	
Least transverse diameter of centrum	85·	
Distance between extremities of transverse processes	680·	
Antero-posterior diameter of opening between transverse processes of above vertebræ	150·	
Tranverse diameter	115·	
Antero-posterior diameter (approximate) of shaft of femur	230·	
Transverse diameter	350·	

These dimensions would indicate for the entire animal a length of probably fifty to sixty feet. It was apparently an herbivorous reptile, and as it is quite distinct from any hitherto described, the species may be called *Titanosaurus montanus*. It was perhaps a distant ally of the comparatively small *Hadrosaurus agilis* Marsh, the only Dinosaur hitherto found in the Cretaceous of Kansas.

With the remains here described were found portions of a much smaller carnivorous reptile of the same order, which apparently belongs to the genus named by Cope *Lælaps*.* These remains, with those already noticed, will soon be more fully described by the writer. Their locality is in the Dakota group of Colorado, on the eastern flanks of the Rocky Mountains, where they were discovered by Professor Arthur Lakes and Captain H. C. Beckwith, U. S. N.

Yale College, New Haven, June 20th, 1877.

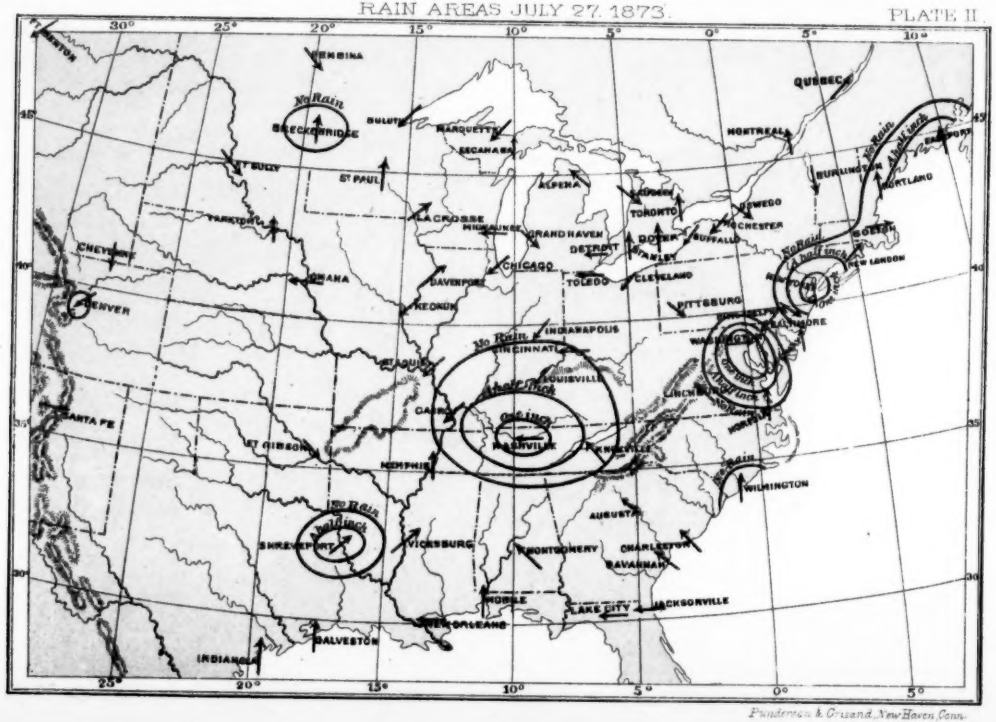
* This name *Lælaps* is preoccupied, having been used by Koch in 1835, and again by Walker in 1843. It may, therefore, be replaced by *Dryptosaurus*. This genus is allied to *Megalosaurus*, and is represented in American Cretaceous strata by several species, among them *Dryptosaurus aquilunguis*.

RAIN AREA OCT. 20 1873. PLATE I.

Photolithographed by Osborne, New Haven Conn.

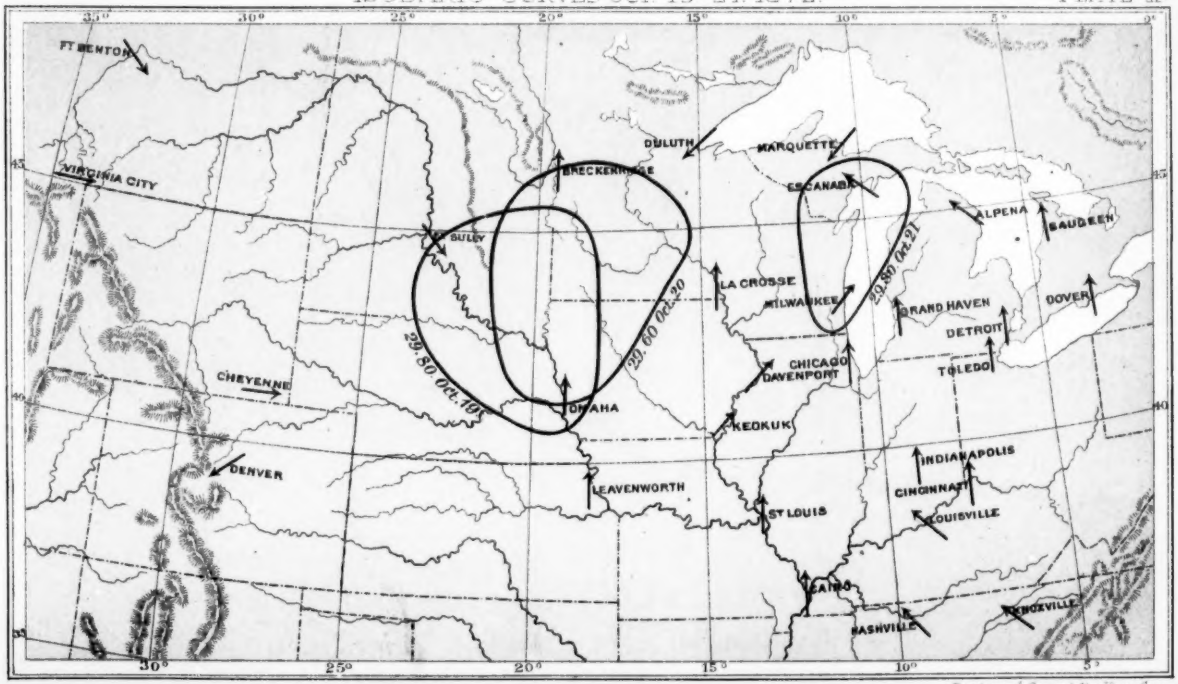
RAIN AREAS JULY 27. 1873.

PLATE II.

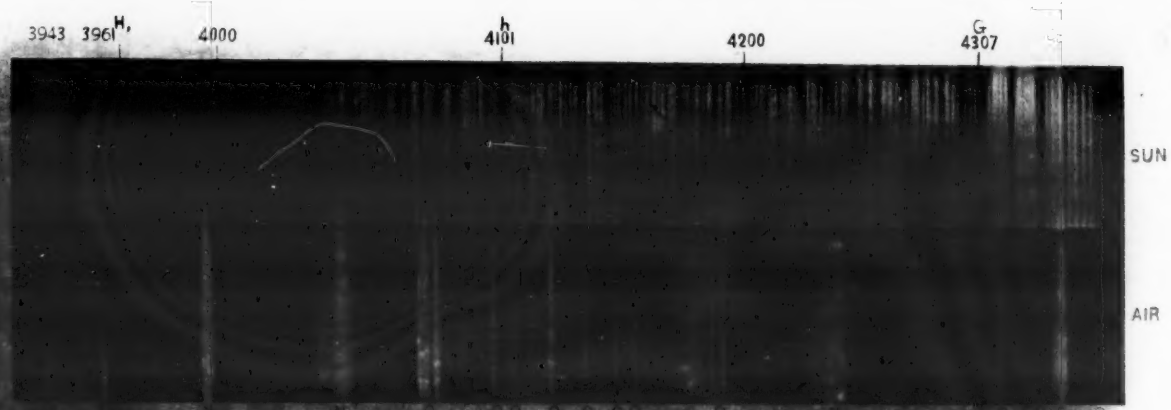


Punderson & Orsand, New Haven, Conn.

ISOBARIC CURVES OCT 19-21. 1872. PLATE II.



Henderson & Critsend, New Haven, Conn.



DISCOVERY OF OXYGEN IN THE SUN BY PHOTOGRAPHY. BY PROFESSOR HENRY DRAPER.

The upper part of the photograph is the spectrum of the sun, the lower part is the spectrum of the Oxygen and Nitrogen of the air. The figures on the margin are printed with type on the negative; with this exception the photograph is free from marks of any kind. O indicates Oxygen, N, Nitrogen, Fe, Iron, Al, Aluminium. The figures above the Sun's spectrum are wave-lengths. G, H, and h are prominent lines at the violet end of the spectrum. The principal point to examine is the coincidence of the bright Oxygen lines with bright lines in the Solar spectrum. The picture is printed from Draper's original negative by Bierstadt, Dry Plate Process.